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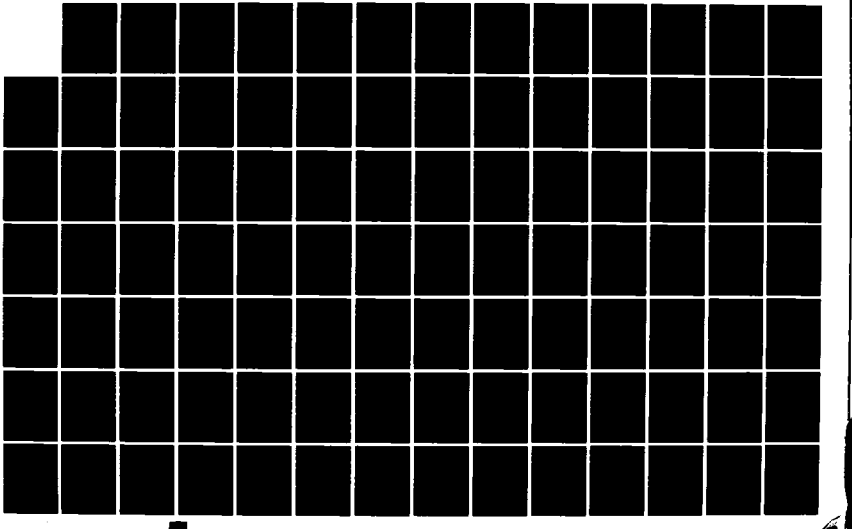

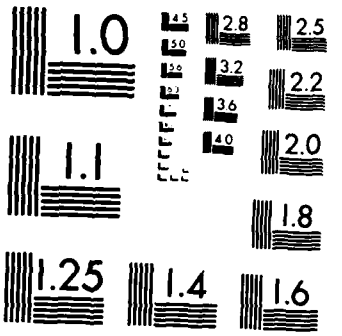

Report No. R-20-82-004

APPLICABILITY OF EXISTING C^3 VULNERABILITY AND HARDNESS ANALYSES TO SENTRY SYSTEM ISSUES

by

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C^3	PROPAGATION		VLF

20 ABSTRACT (Continue on reverse side if necessary and identify by block number) This report is a compilation of abstracts resulting from a literature search of reports relevant to Sentry system C^3 vulnerability and hardness. Primary sources consulted were the DOD Nuclear Information Analysis Center (DASIAC) and the Defense Technical Information Center (DTIC). Approximately 175 reports were reviewed and abstracted, including several related to computer programs for estimating nuclear effects on electromagnetic propagation. The reports surveyed were ranked in terms of their importance for Sentry C^3 V&H issues.

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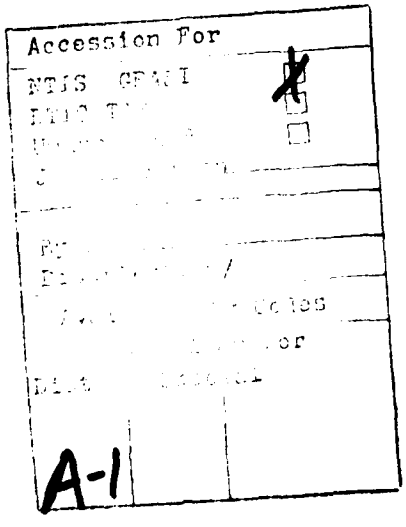

LIST OF FIGURES

1. INTRODUCTION

The Sentry System is a Ballistic Missile Defense (BMD) concept designed to protect the MX missile (and possibly Minuteman as well) from ballistic missile attack. As the MX basing modes have evolved over the past few years toward the currently preferred Closely Spaced Basing (CSB) or "Dense Pack" array, the Sentry concepts have adjusted to match the new defense requirements. All of the Sentry designs, however, have a number of elements in common: they employ multiple radars and multiple interceptor locations; they are in close proximity to the defended missile complex, and they provide for essentially autonomous defense operation once permission to fire has been received. The Sentry Command, Control and Communications (C^3) system ties the Sentry components together into an operational entity, and provides links between Sentry and higher command authority. C^3 links are needed to connect the radars, interceptor farms, and battle management center together. Because the Sentry deployment is relatively compact, land line or radio links tying the complex together can be short (less than 100 nmi) and line-of-sight (LOS) radio links are feasible.

Besides these links within the complex, other longer-range communications paths will be required. Most obvious of these is the linkup with higher command authority (HA), necessary to initiating defense actions and controlling system operation. In addition, a link may be needed to a long range or initial acquisition radar, located at some distance from the main Sentry deployment, and to an Optical Adjunct aircraft, which will be located several hundred miles to one side of the Sentry system. These communications pathways must employ beyond LOS transmission means, or possibly LOS links to elevated platforms.

To meet the requirements for adequate, survivable communications during the trans and post attack threat environments, several different types of communications have been postulated for Sentry. The C^3 links all have in common stringent requirements for survivability in the face of a very severe nuclear threat. A number of different communications concepts have stemmed from the overall Sentry C^3 requirements. One possibility for internetting the

system ground-based elements is the use of buried, hardened fiber optics (F/O) cables. Fiber optics cables have the desireable property of being insensitive to the electromagnetic pulse (EMP) environment. Radio links studied include buried LF/VLF and HF antennas (MF has also been considered), and UHF hardened and pop-up antennas. No survivable satellite links are planned at this time. These radio links would provide connectivity to the airborne platforms of interest to Sentry, as well as communications among the Sentry ground elements.

Titan Systems, Inc. has the responsibility, under BMDSCOM Contract DASG60-82-C-0069, to assist the Sentry Program Office in the evaluation and assessment of the Sentry C^3 vulnerability and hardness work being performed by the Sentry prime contractor and associated subcontractors. Kaman Sciences (Colorado Springs, Colo.) is assisting in this effort as a subcontractor to Titan. As part of the contract activity, a literature search and review of existing documents that might be relevant to Sentry C^3 survivability has been carried out. Two major areas were emphasized in the literature review: the first was the vulnerability of the communications ground nodes (especially antennas) to various nuclear effects, and the second was a survey of radio or other electromagnetic interference arising from nuclear burst interactions. This report contains references and abstracts of the documents reviewed, along with a preliminary critical estimation of their value to the Sentry V&H analyses. This bibliography is given in Appendix A. This compilation of abstracts will provide a convenient reference and guide to the literature for those who will be pursuing specific areas in more detail.

The bibliography is arranged chronologically with the most recent reports listed first. Each report is given a number; there are over 150 references cited here. The references and abstracts are given in the format shown in Figure 1. After each abstract, some additional information gleaned from the review is provided. For some reports, a commentary on general usefulness or on relationships to other reports is provided. The value of the report to Sentry is then estimated in one of four categories: 1) especially valuable; 2) useful; 3) useful in limited areas; and 4) of little value to Sentry. It should be emphasized that these ratings are subjective and apply

1. Document Identification Format

(a) Author(s), (b) Title (in quotes), (c) Document identificatioon numbers, (d) Corporate author and location, (e) Date, (f) Classification, (g) AD number (if applicable).

Example:
Gordon J. Fulks, "HF/VHF Propagation in a Nuclear Environment: Bomb Mode Phenomenology." DNA 5201F; MRC-R-455. Mission Research Corp., Santa Barbara, California. 1 December 1979 (S/FRD). AD-C028252

2. Scope/Abstract

The author's abstract is used if suitable. The abstract includes the purpose of the report; major issues; what was studied; conclusions; and cross references of particular interest.

3. Comments

The comments are added by the reviewer to point out features of the report of particular interest to Sentry.

4. Evaluation

The utility of this report for Sentry C^3 V&H purposes is estimated (subjectively) and placed in one of four categories: Especially valuable; useful; useful in limited areas, and of little value to Sentry. Most reports rated especially valuable are compilations or overviews of important phenoomenology or C^3 systems.

Figure 1. Document Review Format

solely to the value of a report in the context of Sentry C^3 V&H; documents of no particular interest to Sentry C^3 might be exceedingly informative for other studies or systems.

2. LITERATURE SURVEY

There are several types of data that are to be surveyed as part of the Sentry C^3 V&H contract. These are listed at the top of Figure 2 and include Sentry C^3 and threat data as well as the more general nuclear effects survey. As pointed out in the figure, the Sentry design concepts have been in a state of flux over the past year or so because of the uncertain status of MX basing.* As a result, most of the recent documentation on Sentry is in the form of briefings, interim reports, and draft documents. These materials are being collected for internal use but are not abstracted in the Appendix.

The rapidly evolving Sentry design concepts have also inhibited issuing of a final threat description for the system. There are studies, notably one by Horizons Technology, Inc., that provide threat analyses for the MX C^3 system and contain relevant information for Sentry C^3 as well (Ref. 1). This and other formally documented threat data mostly refer to previous MX basing modes, and the structure and timing of attacks against a Dense Pack array will be quite different than for the Multiple Protective Shelter system. Nevertheless, much of the information in existing threat reports is still useful and directly applicable to the Sentry design.

Most of the literature search effort has been devoted to identifying and evaluating reports that deal with nuclear effects on C^3 systems. There are a large number of DoD-generated reports in this area, but there is no single convenient repository where all the useful reports can be obtained. The major source of DoD reports is the Defense Technical Information Center (DTIC), formerly the Defense Documentation Center (DDC). This repository contains about 2,000,000 reports and other items covering a time frame all the way back to World War II.

*Earlier studies of MX/Minuteman went under the acronym LoAD, for Low Altitude Defense system.

- DATA TYPES TO BE SURVEYED:
  - SENTRY C^3 CONCEPT DOCUMENTATION
  - THREAT DOCUMENTATION
  - RELEVANT NUCLEAR EFFECTS DATA
- OVERALL MX AND SENTRY SYSTEM CONCEPTS MUST ALSO BE MONITORED
- SENTRY C^3 CONCEPTS HAVE BEEN IN A STATE OF FLUX
  - MUCH RELEVANT MATERIAL IN BRIEFINGS, INTERIM REPORTS
  - V&H ANALYSES ARE STILL PRELIMINARY
- THREAT INFORMATION IS CONTAINED IN A RELATIVELY SMALL NUMBER OF DOCUMENTS
- NUCLEAR EFFECTS DATA IS VOLUMINOUS BUT SCATTERED
  - DASIAC LIBRARY
  - DTIC REPORTS
  - DNA LIBRARY
  - OTHER SOURCES

Figure 2. Applicability of Existing C^3 V&H Studies.

Another more specialized library is the DoD Nuclear Information and Analysis Center (DASIAC), one of several Information Analysis Centers managed by DoD. Many reports dealing with topics related to nuclear weapons are acquired by DASIAC, including many that are not available at DTIC. Another source of documents related to nuclear weapons technology and utilization is the library at DNA Headquarters, near Washington, D.C. All of these repositories provide both classified and unclassified reports. Other collections of DoD-related materials, including classified documents, are the libraries at the Rand Corporation, the Aerospace Corporation and other FCRC's; in some of the service-maintained libraries at the Pentagon, and in the libraries at the three service academies (West Point, Annapolis, and Colorado Springs). These libraries also have substantial collections of open literature books and journals on scientific and engineering topics. University libraries are also widely available to open literature searches. Because of the specialized nature of the Sentry C^3 Vulnerability and Hardening problem, little of direct relevance would be expected in reports or articles not sponsored by the Department of Defense.

At BMDSCOM request, a survey of the DTIC holdings on C^3-related subjects was initiated by DASIAC personnel. This survey indicated that the number of such reports at DTIC probably exceeded 100,000. For instance, the number of non-duplicated reports for communication equipment and communication systems (as subject areas) was greater than 20,000 each. This volume of reports was too large to search effectively. A more restrictive search was then instituted at DASIAC on reports dealing with nuclear effects on C^3. The DASIAC holdings contain most of the DTIC reports related to nuclear effects, and in addition a large number of documents not entered into DTIC. For instance, essentially all DNA reports are available at DASIAC, although many are not in DTIC files. The subject categories covered by this computer retrieval search are listed in Figure 3. Approximately 1300 entries were found in this search. Listings of the reports were made by subject, by report number, and by DASIAC accession number. These listings were then scanned and approximately 200 reports selected for critical review and abstracting. Reports eliminated from review included older documents, satellite C^3 studies, Navy C^3 studies, and the like.

100 Propagation Studies
- 101 General References and Handbooks
- 109 Bibliographies
- 110 HF, VHF, UHF, Microwave Communications
  - 111 Nuclear test data
  - 112 Natural disturbed atmosphere experiments
  - 113 Theory and computations
- 120 LF, VLF, ELF Communications
  - 121 Nuclear test data
  - 122 Natural disturbed atmosphere experiments
  - 123 Theory and computations
- 130 MF Communications
  - 131 Nuclear test data
  - 133 Theory and computations
- 140 HF, VHF, UHF Radar
  - 141 Nuclear test data
  - 142 Natural disturbed atmosphere experiments
  - 143 Theory and computations
- 150 Optical Radar, Ladar
  - 153 Theory and computations
- 160 Satellite Communications
- 170 Aircraft Communications
- 180 Naval Communications
- 190 Theater Communications
- 200 Civilian Communications
- 210 Tactical Communications

200 C^3 Equipment Physical Vulnerability and Hardness
- 300 General References and Handbooks
  - 301 EMP
  - 302 TREE
  - 305 Air blast
- 309 Bibliographies
- 310 C^3 Unhardened Facilities (including Relay, Switching, etc.)
  - 311 EMP
  - 315 Air blast
- 320 C^3 Hardened Facilities
  - 321 EMP
  - 322 TREE
  - 325 Air blast
  - 327 Ground shock
- 330 Receivers, Transmitters, Processors
  - 331 EMP
  - 332 TREE
- 340 Mobile Equipment Shelters
  - 341 EMP
  - 345 Air blast
  - 346 SGEMP
- 350 Cables
  - 351 EMP
  - 352 TREE
  - 355 Air blast
  - 357 Ground shock
- 360 Antennas, Radars, Ladars, Microwaves
  - 361 EMP
  - 362 TREE
  - 364 Thermal
  - 365 Air blast
- 380 Naval C^3
  - 381 EMP
  - 384 Thermal
- 390 Satellite C^3
  - 391 EMP
  - 392 TREE
  - 393 X-ray
  - 395 Air blast
  - 396 SGEMP
  - 398 ECM
- 400 Tactical C^3
  - 401 EMP
  - 404 Thermal
  - 405 Air blast
- 410 Aircraft C^3
  - 411 EMP
  - 412 TREE
- 450 Civilian Communications
  - 451 EMP
  - 455 Air blast

600 C^3 System Definition
- 601 Large-Scale Networks
- 602 C^3 Facilities
- 610 Satellite Systems
- 611 Naval Systems
- 612 Aircraft Systems

700 Program Descriptions
- 710 Nuclear Test Programs
- 715 Non-Nuclear Atmospheric Programs
- 730 Army Test Programs
- 740 Navy Test Programs
- 760 Agency Test Programs

800 Network Studies
- 810 APACHE
  - 811 Propagation Studies
  - 812 Physical Vulnerability
  - 813 Network definition
  - 814 Program descriptions
- 820 INCA
  - 821 Propagation Studies
  - 822 Physical Vulnerability
  - 823 Network definition
  - 824 Program descriptions
- 830 JEWEL
  - 832 Physical Vulnerability
  - 833 Facility definition
  - 834 Program descriptions

Figure 3. Subject Categories for Nuclear Effects on C^3.

are examined in Section 2 of the report. The probability with time of the antenna being disabled by lightning is also discussed.

Compton currents may be created in the antenna by ionizing radiation, specifically gamma radiation, since the overburden of soil attenuates x-ray radiation to small values. These currents are due to the kinetic displacement of electrons in the antenna wire itself, in the surrounding insulator, and in the soil by ionizing radiation photons. In Section 3 was shown that these currents are not negligible but are small when compared with EMP currents.

Reference: R. St. John and J. Schmelzer, "EMP Study of a Proposed Underground Antenna" AFWL-TR-81-186, Mission Research Corp., Albuquerque, N.M., August 1979. (SRD/CNWDI).

Evaluation: Useful.

3. R. St. John, J. Schmelzer and M. Wolfe, "The EMP Response of the Baum MF Antenna". AFWL-TR-81-196. Mission Research Corp., Albuquerque, New Mexico. January 1982 (U). AD-B064241L.

Scope/Abstract: The early- and late-time response of the Baum MF antenna to an EMP pulse is predicted using a transmission-line approximation. The early-time response included approximations for a horizontal missile shelter and four feed coaxes; 10 kA peaks around 10 us are obtained. The late-time response includes the presence of a long buried power-line which delivers about 250 kA to the antenna and shelter. The shielding to the center of the antenna offered by the perimeter is calculated to be roughly 20%.

Reference: St. John and Gilbert, "Effects of the Power Line on Source-Region-Generated Currents on a Horizontal Shelter and Buried, Medium-Frequency Antenna," AFWL-TR-81-205, Mission Research Corp., Albuquerque, N.M. October 1980. (U)

Evaluation: Useful.

4. Richard St. John and Michael Wolfe, "Nonlinear Coupling Effects and Late-Time Common-Mode Currents on a Buried MF Antenna." Mission Research Corporation, Albuquerque, New Mexico. January 1982. AD B064215L (U).

Scope/Abstract: The hardening techniques of inserting a saturable transformer at the feedpoint of a buried antenna are investigated. For the saturation properties used, the currents were reduced to under a kiloamp for both source-region and high altitude EMP. The effects of breakdown in the lead-in twinax were also investigated.

1. L. A. Wittwer, F. W. Guigliano, R. L. Bogusch and R. W. Kilb, "A Reasonable Worst Case Specification of Nuclear Disturbed Radio Signals", DNA-IR-82-01. DNA in-house report. April 1982 (S).

Scope/Abstract: This report contains the data base of the DNA Reasonable Worst Case Signal Specification and details for its application. This is a companion document to "A Trans-ionospheric Signal Specification for Satellite C^3 Applications," DNA 5662D, 31 December 1980.

Comment: A compendium of information on expected degradation of Satellite Link Communication Systems after a high altitude nuclear event.

Evaluation: Useful in limited areas.

2. R. J. St. John, Schmelzer, and C. Bohling, "Effects of Lightning and Ionizing Radiation on a Proposed Underground Antenna", AFWL-TR-81-187; AMRC-R-206. Mission Research Corporation, Albuquerque, N.M. Feb 1982 (SRD/CNWDI). AD-C028637L.

Scope/Abstract: In this report are computed the worst case lightning and Compton currents likely to occur on a buried medium frequency 440 kHz dipole. Short-circuit currents and open-circuit voltages at the equipment end of the feed line are computed. Insulation gradients and power dissipation in electric surge arrestors are computed. Lightning is shown to be a threat by disruption of the ESA's; the Compton currents are shown to be small in comparison to EMP currents.

Comment: The medium frequency MF antenna proposed for the MX shelter sites consists of two straight buried dipoles. The survivability of the antenna is crucial because it is the primary communication link between the missile and control during nuclear attack. The previous report (reference 1) has investigated the vulnerability of the antenna to nuclear electromagnetic pulse. However, no studies have been made on the effects of ionizing radiation and lightning. This report covers those sources of excitation.

The effects of lightning are considered using a worst case 200 Kamp pulse in the vicinity of the antenna. The survivability of the system is examined in three areas: breakdown of the antenna insulation and/or lead in twinax, the electric surge arrestor (ESA) performance, and the short-circuit current and open-circuit voltage expected at the antenna lead-in at the missile shelter. These vulnerabilities with respect to direct strike and airborne strike

APPENDIX A

REPORT ABSTRACTS AND EVALUATIONS

6. REFERENCES

1. "MX C^3 Survivability and Endurance Analysis, Final Report." HTI McLR 81-035. Horizons Technology, Inc., McLean, Virginia. July 31, 1981. (Four Volume Report). (S).

- NUCLEAR CLOUD LIGHTNING
  - SEVERAL REPORTS HAVE BEEN PUBLISHED ON THIS SUBJECT
  - MOST DEAL WITH PHYSICAL VULNERABILITIES OF ANTENNAS AND OTHER C^3 CONCEPTS
  - LIGHTNING-INDUCED NOISE HAS BEEN MENTIONED BUT NOT ANALYZED
  - PHENOMENOLOGY, ESPECIALLY FOR "DUST CLOUD LIGHTNING," IS HIGHLY UNCERTAIN
- FIBER OPTICS SYSTEM HARDNESS
  - RESEARCHED BY KAMAN SCIENCES
- HARDNESS OF GFE EQUIPMENT
  - BEING PURSUED BY BOTH KAMAN AND TITAN

Figure 6. Special Topics.

5. SPECIAL TOPICS

There were several topics of special interest that were given particular attention during the literature survey. These topics are summarized in Figure 6. The first of these items, nuclear cloud or fireball lightning, has been discussed in several recent reports (see abstracts 2, 15, 54, 151 and 159). A review of this subject for MX communications (Air Force Scientific Advisory Board, 23-24 August, 1982) indicated that nuclear lightning did pose a physical threat of destruction and damage to equipment. This can be countered by standard engineering practice and good design (e.g. the use of ESL's). The problem of noise in communications channels was also recognized, and thought to be solvable because of the short duration of the transient noise. However, it appears that a lightning "bolt" from an ordinary cloud is accompanied by up to half a second of electrostatic discharges, and frequent bolts from a cloud right at an antenna may generate enough noise to mask signal receipt for time periods significant to Sentry. Nuclear lightning may have a shorter generation time and may not involve a return current, but this appears to be an issue warranting further study. A separate open literature search was performed on electromagnetic noise from lightning. This bibliography, along with a few comments on the frequency content of lightning noise, will be presented in a subsequent memorandum.

Figure 6 indicates two other areas of preliminary emphasis. Kaman Sciences will issue a short report on fiber optics response to nuclear radiation. This phenomenology appears to be well understood by the Sentry C^3 community, and no further work is planned on this topic at this time. The hardness of GFE equipment is still an area of active investigation.

4. MAJOR NETWORK STUDIES

There are three major network studies that have been carried out over the past several years and are listed at the end of the subject index of Figure 3. These studies are important because they have been relatively heavily funded, extended over a period of several years, and included a number of equipment tests that contributed greatly to our understanding of communications equipment vulnerability, especially to EMP. The APACHE (Analysis of Pacific Communications for Hardening to EMP) program was oriented toward communications in the Pacific Theater, the CINCPAC area of responsibility. The program objective was to identify communications node vulnerabilities to EMP by both analysis and testing and to make recommendations for correcting any deficiencies uncovered. APACHE was started in 1975 with the Defense Nuclear Agency (DNA) as the Project Manager. DNA also directed the INCA and PREMPT programs. APACHE activity is continuing and reports are still being issued on this project.

The INCA program (INCA = Integrated Nuclear Communications Assessment) pre-dates APACHE and was set up to examine European C^3 and CONUS-to-Europe communications links. Although EMP was emphasized in INCA analyses, other nuclear effects, including nuclear interference with RF propagation, were also considered as part of the program. The INCA project is generally regarded as useful and successful; this success contributed to starting the parallel APACHE effort in the Pacific Theater.

The PREMPT program had as its main objective the assessment of U.S. communications vulnerabiliity to high altitude EMP. A great deal of emphasis was placed on the Autovon network and the switching centers that support this network. Two specific sites, at Polk City, Florida and Delta, Utah, were singled out for particular attention with analyses and tests.

Some of the APACHE, INCA and PREMPT reports were identified as particularly relevant to nuclear effects on Sentry C^3 and have been abstracted in Appendix A. A much more extensive list of references associated with these three projects is given in Appendix C. Some of these reports may be useful for Sentry C^3 problems; others are mere compilations of uninterpreted data, test plans, or facility response predictions that are of minimal carryover value to Sentry.

- ALL OF THE CODES FOR EVALUATING NUCLEAR EFFECTS ON C^3 SYSTEMS ARE LARGE AND COMPLEX
  - PROGRAM UTILIZATION REQUIRES SKILLED PERSONNEL
  - DATA PREPARATION CAN BE TIME-CONSUMING
  - IN MANY CASES NO SIMPLE ANALYSIS OF NUCLEAR/C^3 PROBLEMS IS FEASIBLE
- MOST OF THESE PROGRAMS HAVE BEEN UNDER DEVELOPMENT FOR SEVERAL YEARS
  - SEVERAL HAVE UP-TO-DATE NUCLEAR PHENOMENOLOGY MODELS
- UNFORTUNATELY THE C^3 CODES IDENTIFIED HERE DO NOT REALLY ADDRESS THE SENTRY PROBLEMS WELL
  - MOST OF THE C^3 CODES ARE STRUCTURED FOR LONG (> 1,000 KM) PATH LENGTH
  - ONLY NUCOM AND NORSE COVER FREQUENCIES OF PRIMARY INTEREST TO SENTRY
  - LATE-TIME PHENOMENOLOGY (> 30 MINUTES) IS CAREFULLY TREATED BY THESE CODES, BUT IS NOT OF CRITICAL IMPORTANCE TO SENTRY
- EXISTING CODES MAY NOT BE ADEQUATE FOR THE SENTRY C^3 PROBLEMS

Figure 5. Propagation Code Review: Conclusions.

unique propagation modes is still incompletely understood, HFNET has some character as a research program as well as a systems analysis tool.

The RANC code is a systems-oriented radar blackout code that has been widely used in the BMD community for many years. Although formal development of RANC has been terminated, the code still has a number of users and remains the preferred systems-level radar interference program for many applications. RANC, like ROSCOE and NORSE, is not a communications code but contains phenomenology appropriate to line-of-sight propagation evaluation.

The PNAC program is a network-type code for satellite communications. It was developed for the Air Force (AFWL). STRAT COMMAND is a large scale network-oriented code sponsored by Headquarters, Air Force Studies and Analysis. It handles VLF through satellite frequencies and includes damage to the C^3 nodes as well as propagation interference. The nuclear phenomenology for the satellite section of the code was recently upgraded, and improvements to the VLF/LF sections of the program are planned.

The findings of this short survey of propagation codes are summarized in Figure 5. The conclusion, stated in the figure, is that the existing codes are probably not adequate for the entire range of Sentry C^3 V&H issues.

program easier to use than ROSCOE. Although neither ROSCOE nor NORSE are C^3 analysis codes, their nuclear phenomenology is compatible with frequencies used for line-of-sight communications.

The WEPH program was maintained for many years as the nuclear effects standard for C^3 codes. The most recent version of the code is WEPH-VI. Development of further versions of WEPH has been halted, at least for the time being, but the program is still available and current enough to be useful. There are no electromagnetic propagation sections to WEPH, so it is not a self-contained C^3 code. The WEPH phenomenology is being replaced by models in the WEDCOM and WEFCOM programs. This latter code, still in development, will emphasize nuclear effects on the E and F layers of the atmosphere. The initial version of WEFCOM is expected in about two years.

The final category of C^3 programs are those used for systems analysis. These programs contain approximations or phenomenology limitations that are inserted to reduce the computer run time so that either very large problems can be handled, or wide ranging parametric analysis can be done for smaller problem sets. The SIMBAL code is a large-scale program designed specifically to analyze the Minimum Essential Emergency Communication Network (MEECN) C^3 system. This is a worldwide communications net with hundreds of nodes and links. Its survivability and performance are typically evaluated against a RISOP attack, which contains hundreds of bursts. Because of the large number of entities to be handled, simplifications have been introduced into SIMBAL to reduce run time. One of the simplifications was the utilization of precomputed data for certain specific MEECN frequencies. As a result, SIMBAL will not handle an arbitrary frequency input, which limits its application for general problems.

HFNET is a multiburst, multilink code that operates in the same general frequency regime as NUCOM (HF and VHF). The propagation simulation is simpler than for NUCOM, and the nuclear phenomenology is not as all-inclusive as for NUCOM. However, HFNET does model some potential propagation modes that are not treated by any other program. Because the phenomenology for these

The WEDCOM code is a detailed treatment of propagation in a nuclear environment covering frequencies in ELF, VLF and LF. Within this frequency range there are no restrictions on the frequencies used. WEDCOM provides a state-of-the-art representation of nuclear weapons effects. However, only a small number of links and bursts can be handled. The most recent version of the program, WEDCOM IV, is slow running but the version being worked on now (WEDCOM V) will be faster and will also have an enhanced capability for ground wave propagation calculations.

The WESCOM code is another detailed, up-to-date model that describes nuclear effects on satellite communications. WESCOM is structured for frequencies at VHF and above, since these line-of-sight links are the ones employed in satellite C^3 links. Late time (> 30 minutes) high-altitude nuclear effects such as striations and scintillation are modeled by the code, and the simpler modulation schemes can be treated. Since SENTRY does not (at present) involve a satellite link, WESCOM is not directly applicable to SENTRY C^3 problems.

The NUCOM code has evolved through several versions, the most recent of which is NUCOM III. NUCOM is an HF frequency code which is most useful for communication estimates over distances greater than line of sight (e.g., 500 km or more). The limited frequency range--roughly 2 MHz to 30 MHz--limits the application of NUCOM in SENTRY analyses, but it should be useful for some problems. A variation of NUCOM called NUCOM/BREM extended the NUCOM II phenomenology to include line-of-sight propagation to elevated platforms (e.g., aircraft).

ROSCOE models radar and optical sensors operating in a nuclear environment, and is not a C^3 code per se. However, the nuclear phenomenology is treated in detail, especially at early times (< 30 minutes). ROSCOE was intended to be a "laboratory standard" code for radar blackout and IR sensor nuclear interference. Unfortunately ROSCOE is difficult to run, and has not been widely applied by the nuclear effects community. NORSE is a radar-oriented blackout code based largely on ROSCOE phenomenology. An attempt is being made in the NORSE development to simplify input and output and make the

- THERE ARE ONLY A LIMITED NUMBER OF COMPUTER CODES FOR EVALUATING NUCLEAR EFFECTS ON C^3 SYSTEMS
- RESEARCH-ORIENTED CODES
  - MRCSIM
  - SCENARIO
  - NOSC PROPAGATION CODES
- ENGINEERING CODES
  - WEDCOM
  - WESCOM
  - NUCOM
  - ROSCOE
  - NORSE
  - WEPH
- SYSTEMS ANALYSIS CODES
  - SIMBAL
  - HFNET
  - RANC
  - PNAC
  - STRAT COMMAND

Figure 4. Codes for Propagation in a Nuclear Environment

3. PROPAGATION CODE REVIEW

One of the areas of particular interest in this literature survey was an identification of computer codes for evaluating nuclear interference with electromagnetic propagation, specifically with RF C^3 systems. With the assistance of personnel at Kaman Tempo, several codes were reviewed and brief descriptions of the most prominent of these are included below.* A bibliography of reports describing some of these codes is given in Appendix B.

Computer programs for analysis of nuclear effects on C^3 systems can be grouped into one of three categories: research tools, engineering codes, and systems analysis codes. Figure 4 lists a number of propagation codes grouped into these categories. Research codes tend to be based on "first principles" with physics modeling as complete as is possible. The general purpose of these codes is to increase our understanding of both communications and nuclear effects phenomenology and of their interactions. Since these codes are research tools they are continually being changed and are, as a rule, poorly documented. MRCSIM, listed in Figure 4, is a collection of programs usually run in three parts for analysis of selected propagation problems. SCENARIO has some documentation; it uses a high altitude grid and a hydro-code-like approach to satellite communications. The NOSC (Naval Ordnance Systems Command) codes are detailed propagation simulations mostly at lower frequencies. These are combined with WEPH code phenomenology to give nuclear interference effects.

Engineering codes will use the most accurate representation of the phenomenology consistent with our understanding of the technology, unless computer requirements become prohibitive. These programs can be used for studies on problems of restricted scope, but are not usually fast enough for extensive parametric analysis. Most of these programs are documented and available within the community for C^3 and nuclear effects studies.

*A more thorough summary of code capabilities will be issued by Kaman-Tempo in the near future.

The DASIAC searches were supplemented by a selective review of DTIC holdings. Recent Technical Abstract Bulletins (TABs) were checked for current work, since most of the activity directly related to Sentry would have occurred within the past two or three years.

The documents selected for the Bibliography were produced by a number of different organizations, with Mission Research Corporation, Kaman-Tempo (formerly GE-Tempo), Stanford Research Institute and Computer Science Corporation (CSC) all prominent as corporate authors. The two most active sponsors of V&H work related to C^3 systems were the Defense Nuclear Agency (DNA) and the Air Force Weapons Lab (AFWL). Other sponsors of relevant work included BMDSCOM and the Defense Communications Agency (DCA). This mix of contractors and sponsors would be quite different for less narrowly defined subject areas; for instance, including satellite C^3 brings in new sponsors (Air Force Space Division) and contractors (TRW, Hughes, etc.).

Breakdown was found to occur near the feedpoint and near the shelter. Late-time, common mode currents on the shield and core conductors of the twinax were found using a combination of transmission line and lumped parameter techniques. The peak currents were found to be smaller than for a worst-case excitation of the antenna, however, the energy dissipation requirements were found to be higher.

Evaluation: Useful

5. Klaus Opalka, "A Simple Model for Predicting the Blast Loading of Box-Like Structures", Tech Report ARBRL-TR-02385, Ballistic Research Laboratory. Aberdeen Proving Ground, Maryland. December 1981 (U) AD B062349L.

Scope/Abstract: This report describes a simple model for predicting the loads on box-like target structures subject to air blast. A computer code has been developed at the BRL to quickly obtain a prediction of the average surface loads on the target without recourse to a hydro code. The model has shown very good agreement with existing and experimental data.

Comment: This report describes a model for the prediction of blast loading on box like structures and discusses the results, which are compared with available experimental data. The model was developed to obtain blast loading predictions without having to resort to hydrocode computation which is usually quite involved. The model employs analytical and empirical procedures. The latter are based on experimental work done previously and primarily at the BRL. A computer code was written using this one dimensional flow model and applying it to targets which can be approximated by a series of rectangular parallelopipeds. In this report the physical phenomena of high energy explosions generating blast waves is outlined. The physical laws of one dimensional gas dynamics used in the model are compiled and the target loading procedures are described. The blast loading predictions obtained with this model are compared with available experimental data and other computations. The model developed here is in very good agreement with the existing experimental data and with the 3-D HULL hydrocode model. The report contains a FORTRAN listing of the model and provides information on comparisons between HULL and BLOP, the simplified model. If blast load predictions are required this model would appear to be a reasonable one to use.

Evaluation: Useful in limited areas.

6. Carl J. Lauer, "Angle of Arrival Fluctuations in a Nuclear Dust Cloud Pedestal." DNA-TR-81-32; MRC-N-476. Mission Research Corporation, Santa Barbara, California. 1 August 1981 (U). AD-A112260

Scope/Abstract: Angle-of arrival fluctuations from propagation through a nuclear dust cloud pedestal have been identified as a potential source of system degradation for a ground-based tracking radar. This note investigates these angle-of-arrival fluctuations as measured by a 3 meter diameter lens-type antenna operating at an RF wavelength of 3 centimeters. Since large uncertainties exist in the current knowledge of the dust environment, this investigation is performed parametrically over what are estimated to be reasonable ranges of the key variables involved. The effects of antenna aperture taper, target elevation, radar height, dust material properties, dust distribution with height and also the size distribution of the irregularities are investigated.

Comment: A related useful document is: S.L. Gutsche, "X-Band Attenuation from a Nuclear Dust Cloud Pedestal: Bounding Calculations and Determination of Sensitivity to Key Parameters." MRC-N-464. Mission Research Corp., Santa Barbara, Cal. May 1981 (U).

Evaluation: Useful.

7. L. J. Mabie, L. C. Jaffe, and J. H. Harrington, "Command, Control and Communications and Intelligence (C^3I) Process Flow Analysis Vol I, Executive Summary." DNA 5836F-1; BETAC 81311V.1. BETAC Corporation, Arlington, Virginia, July 1981 (S).

Scope/Abstract: Command, Control, and Communications and Intelligence Process Flow Analysis is a comprehensive study of U.S. and NATO effectiveness in countering Soviet Warsaw Pact offensive initiatives in the central region of NATO, primarily related to the interdiction and disruption of the Soviet second operational echelon. The primary objective of this study is to evaluate the NATO U.S. Command Control and Intelligence structure which can effectively plan, direct control and response, assess damage, retarget, and direct follow-up strikes as required. The time frame of the study is the 1983 to 1990 period with emphasis placed on the central region C^2I systems that are estimated to be implemented at that time. This study focuses on the use of U.S. NATO tactical aviation, F-111 primarily, the Pershing II ballistic missile, and the ground launched cruise missile, (GLCM) as the candidate theater nuclear force (TNF) weapons systems. The operational environmental framework includes the threat scenario, intelligence collection

systems, the U.S./NATO European C^2I structure and ADP systems that support that structure, communications systems, and weapons system. The functional flow of C^2I processes were constructed to determine timing data. The collection scenario was developed to derive target data timing necessary to determine the effectiveness of the candidate systems and a selective release of nuclear weapons as a counter to the second echelon forces. Various options, conditions, and excursions were inserted into the model and assessments made of the results. For these assessments conclusions have been drawn, recommendations made for the improvement of the deep interdiction mission.

Volume 1 contains a brief description of the study and provides the general results and conclusions of the analysis. Volume 2 is the main report, and Volume 3 contains appendices.

Evaluation: Useful.

8. J. W. Carpenter, R. T. Donahue, H. A. B. Gardiner, C. H. Humphrey, J. A. Jamieson, and J. S. Titus, "The Effects of Atmospheric Nuclear and Natural Backgrounds and Signatures on Advanced Optical Systems. Vol 2" AFGL-TR-80-0215, Visidyne Corp. Burlington, Massachusetts July 1981. (SRD)

Scope/Abstract: This report contains a variety of theoretical and experimental data and evaluations related principally to improved understanding of the phenomology of upper atmospheric nuclea detonations and effects on advanced optical detection systems.

Comment: Concerned with high altitude bursts.

Evaluation: Useful in limited areas.

9. John P. Incerti and Steven L. Gutsche, "Relay-Capable Network Performance in Severe Nuclear Environments." DNA 5754; MRC-R-622. Mission Research Corporation, Santa Barbara, California. May 31, 1981. (S). AD-C028154L.

Scope/Abstract: The advantages of Relay-Capable HF terminals for possible Emergency Action Message (EAM) missions over those unable to operate in a network configuration are demonstrated for two nuclear scenarios. Network connectivity is examined for various numbers of allowed relays and frequency ranges.

Comment: This report briefly describes the absorption environment for both the NICKEL PLATE and DIME NOVEL scenarios as predicted by the computer code HFNET. The report provides a model of a relay

network during a nuclear event, the ability of the network to operate, and the sensitivity of the network to critical parameters.

References:

1. Gutsche, S. L. "Effects of NICKEL PLATE and DIME NOVEL Laydown on an Adaptive HF/VHF System Concept" (U) DNA 4952T; MRC-R-428, Mission Research Corp., Santa Barbara, California. April 1979 (S). AD-C023582.

2. Sowle, D. H. and W. A. Schleuter, HFNET: A Computer Program to Calculate Nuclear Effects on HF/VHF Communications Systems(U) DNA 5137T-I; MRC-R-515 Vol I, Mission Research Corp., Santa Barbara, California. November 1979 (CFRD). AD-E301061

Evaluation: Especially valuable.

10. W. Gilbert, "Evaluation of a C^3 Environment Projected to Support an Advanced ICBM System", R&D Associates, Marina Del Rey, California. May 1981. (S) AD C025761L.

Scope/Abstract: This report discusses the current C^3 capability for supporting a new land-based ICBM system. It attempts to project the environment into the 1980's and 1990's to evaluate performance. Some suggestions are made for the elimination of perceived deficiencies.

Evaluation: Useful.

11. J. Workman and F. Chu, "Ground Based C^3 Facilities Hardening and Validation. Nuclear Environment Models for Communication Analysis." AFWL-TR-80-67. Berkeley Research Associates, Berkeley, California. May 1981 (U) AD-B057725L.

Scope/Abstract: This report summarizes (in approximately 35 pages) the rationale, physical model and utility of the SCENARIO code which models the disturbed ionosphere. SCENARIO is a program for satellite signal analysis.

Comment: This report is technical and of little general interest.

Reference: Stagat, R. W. and D. S. Sappenfield, "SCENARIO: A program for Satellite Signal Propagation Analysis Applications." AFWL-TR-78-137. AFWL, Kirtland AFB, N. M. 1979 (U).

Evaluation: Of little value to Sentry.

12. R. J. Jordano, and W. S. Knapp, "BMD Radar Systems Degradation in Nuclear Environments", (no report no.) Kaman Tempo, Santa Barbara, California. 24 April 1981 (C).

Scope/Abstract: A set of viewgraphs and text to describe the effect of nuclear events on Radar Systems. A good graphical summary.

Evaluation: Useful.

13. I. N. Mindell and Ms. B. J. Ryan, "DNA EMP Simulation and System Hardening Symposium. Vols. I, II & III." DNA 5702P-1, 2 and 3. IIT Research Inst., Chicago, ILL. 1 April 1981. Vol. I, AD-C027547 (SRD). Vol. II, AD-B066851L (U). Vol. III, AD-B066852L (U).

Scope/Abstract: Classified (Vol. I) and unclassified papers from a symposium held in October, 1980. Several relevant papers on EMP effects on C^3/C^4 systems are included. A good summary paper by George Baker, DNA and Walter Hardwick, Jaycor, on the use of Electro-Optical Technology to achieve EMP hardness has an extensive bibliography. EMP test facilities, coupling, hardness surveillance, and other areas are covered.

Evaluation: Especially valuable.

14. John Hamre, Richard H. Davison, and Peter T. Tapgaard, "Strategic Command Control and Communications (C^3): Budgetary Implications of Alternative Modernization Approaches," Report 970/JH, Congressional Budget Office National Security and International Affairs Division, Washington, D.C. February 1981 (S) AD-C026811.

Scope/Abstract: This study evaluates the ability of the current strategic Command, Control, and Communications (C^3) system to support U.S. strategic doctrine and ways to upgrade the system to meet expanded requirements. The study outlines four strategies for future investment in strategic C^3. The first is to correct outstanding system deficiencies. The second stresses expanded system capabilities in the trans-attack period. The third examines systems to improve system C^3 endurance. The fourth alternate is a comprehensive strategy encompassing all of the above. The study notes that even the most expensive alternate is likely to consume only modest funds relative to the strategic force expansion projected over the next decade.

Comment: This document provides a review of the general strategic C^3 system in the United States from the President down to the operational aspects. The document talks about deficiencies in this system and areas where certain parts of the system do not function at the most optimal levels. Some indications of alternative ways of correcting deficiencies or revising the system are presented. The document would be of value in understanding the overall strategic approaches for Command, Control and Communications in time of emergency in the United States.

Evaluation: Especially valuable.

15. Robert L. Gardner, James L. Gilbert, Conrad Longmire, and Michael H. Frese, "Nuclear Lightning. Volume I: Currents Carried by the Discharge." AFWL-TR-81-192, Vol I. Mission Research Corp., Albuquerque, N. M. February 1981 (U).

Scope/Abstract: This report presents a model consistent with the observed features of nuclear lightning. The problem is divided into two parts. First, an electrostatic problem was solved modeling the lightning channel as a perfectly conducting rod, to determine the focusing of fields and currents near the tip of the discharge. Second, a detailed self consistent model of the air chemistry, heating rates and current flow patterns is presented. From the second model the growth rate of the tip is shown to be between .8 x 10^5 M/S and 1.5 x 10^5 M/S, consistent with photographic evidence, and the tip remains sharp as observed rather than becoming bulbuous and dissipating.

Additional References:

1. M.A. Uman, D.F. Seycord and D.H. Price and E.T. Pierce, Lightning Induced by Thermonuclear Detonations. Journal of Geophysical Research, No. 77, p. 1591, 20 March 1972.

2. R.D. Hill, Lightning Induced by Nuclear Bursts. Journal of Geophysical Research, Volume 78, p. 6355, 20 September 1973.

Evaluation: Useful.

16. C. J. Wolf, "Dust Entrainment and Transport by Turbulence in Nuclear Burst Flowfields", DNA 5767F, FR-81-14/AS, Acurex Corporation, Mountain View, California. 1 February 1981 (U). AD-B064726L

Scope/Abstract: A theory is developed for entrainment (dust sweep-up) and turbulence-particle interactions in flowfields driven by nuclear bursts. The theory is described by a coupled set of partial differential equations; for the fluid, the particles, the turbulence, the mutual interactions and with links between field variables and boundary conditions.

The theory is shown to have the general characteristics of laboratory data for two-phase flow over a sand bed in that it has the capability to predict the measured profiles of mean fluid velocity and particle concentration. It can also be extended to include a transport equation for the mean square of the particle concentration fluctuations, which is an important parameter for predicting electromagnetic transmissions through dusty flows.

The turbulence model is an extension of the two-equation type which has a transport equation for the turbulent intensity, or the kinetic energy of the fluid velocity fluctuations, and another transport equation for the dissipation rate of turbulent kinetic energy. The extension consists of an additional term in the dissipation rate equation which models the damping effect of particles on the fluid turbulence. The particle phase equations are shown to contain a Reynolds stress which explains particle diffusion in the direction that is perpendicular to the mean flow and opposite gravity. Several alternatives for modeling this stress in terms of the turbulent intensity are outlined.

The entrainment model is derived from the experimental observation that turbulent bursting is the mechanism for transporting particles from the surface to the interior of the flow. The model uses the bursting frequency and the local maximum turbulent intensity as fundamental variables.

Evaluation: Useful.

17. Timothy L. Stephens and Kenneth Schwartz, "Nuclear Phenomenology for Ballistic Missile Defense (FY 80)", DNA 5700F; KT-81-006(R), Kaman Tempo, Santa Barbara, California. 31 January 1981 (C/FRD).

Scope/Abstract: This volume documents continued work on the characterization of environments resulting from atmospheric nuclear detonations, as they affect Ballistic Missile Defense systems. Models of non-fireball disturbed region chemistry have been improved to handle

very high energy deposition levels. Atmospheric heave predictions of ROSCOE and WOE II have been compared with hydrocode results. WOE II has been modified to handle up to 50 nuclear bursts. Plans for NORSE (a BMD derivative of ROSCOE) were formulated.

Evaluations: Especially valuable.

18. Charles E. Needham and Joseph E. Crepeau, "The DNA Nuclear Blast Standard (1 Kt)", DNA 5648T; SSS-R-81-4845, Systems, Science and Software, Albuquerque, New Mexico. 30 January 1981 (U).

Scope/Abstract: A set of subroutines has been developed which provide complete definition of the blast environment resulting from the free air detonation of a one kiloton device in a sea-level atmosphere. The subroutines provide the pressure, density, and velocity a function of space and time (from 1 ms to several minutes).

The analytic fits are compared with results of hydrodynamic calculations and with experimental data. Blast parameters are a function of radius at a given time. By successive calls to the routines, time histories of the various parameters may be generated.

A complete set of scaling routines is included to permit definition of blast waves resulting from arbitrary yield and altitude combinations. A real gas equation of state for air and a model of the US Standard atmosphere are also included.

This report supercedes AFWL-TR-73-55 and AFWL-TR-73-55 (REV).

Evaluation: Useful.

19. Harold L. Brode, Dale A. Larson, Richard D. Small, Stephen J. Speicher, and Frank J. Thomas, "Fire, Airblast, and Underground Effects from Nuclear Explosions - Some Current Progress." DNA 5741T. Pacific-Sierra Research Corporation, Santa Monica, California. 1 January 1981 (U).

Scope/Abstract: This report covers research on nuclear effects related to topics such as air blast, large area fires and underground testing. Approximate analytic solutions are provided for the peak overpressures (including the double peak phenomena) and dynamic pressure as a function of height of burst and time.

Fires accompanying nuclear warfare are covered from three perspectives. The first is a general review of urban superfires. This is followed by an analytic modeling of such fires as pertains to fire

generated winds, air temperature and atmospheric effects. The model derives simplified differential expressions for the gas dynamics of large scale fires. Finally, a methodology for predicting fire damage is outlined and a flow diagram for a fire damage prediction program is presented.

Current information on cavity decoupling of underground nuclear tests from different seismic signals is reviewed and the potential contribution from initial underground testing is evaluated. Also discussed is the application of nuclear explosives to drive a large shock tube allowing high overpressure and fireball simulations. Questions regarding instrumentation and structural response in this hostile environment are explored. Other alternatives for simulating high pressure flows are examined and some details of the nuclear shock tube are discussed including a method for reducing radioactive contamination in the test section.

Evaluation: Useful.

20. Charles L. Rino, "Propagation Effects in Disturbed Environments", DNA 5637F, SRI International, Menlo Park, California, January 1981 (U).

Scope/Abstract: Radio Beacon diagnostics are still the least expensive means of obtaining data on naturally occurring and artificially induced striations. To exploit this capability fully, a theory is developed for interpreting rocket-beacon data when the velocity component along the line of sight to the receiver is much larger than the transverse component. A simple and direct relationship is shown to exist between the beacon-phone Spectrum and the one-dimensional in-situ spectrum that does not involve any unknown parameters, such as the path length within the disturbance.

Comment: This report describes a method for evaluating data to determine information about the disturbed environment.

Evaluation: Useful in limited areas.

21. J. F. Vesecky, J. W. Chamberlain, J. M. Cornwall, D. A. Harmmer, and F. W. Perkins, "Irregularities in Ionospheric Plasma Clouds: Their Evolution and Effect on Radio Communication", JSR-80-15. SRI International, Arlington, VA. Sept. 1980, (U) AD-A099770.

Scope/Abstract: This is an unclassified report which describes the effect of high altitude nuclear explosions on radio communication to satellites and high frequency skywave circuits. In general, the description is a review of the physical phenomena that occur plus a

discussion of the late time effects which may affect this radio propagation. A general review of the problem is given and additional research in the area is suggested which might yield answers to those questions which the authors felt had not been carefully treated. In particular data requirements to back up computer calculations are discussed.

Evaluation: Useful.

22. I. James Carney, Arnold Baker and Harry G. Reed, "EMP Protection Assurance, Surveillance and Maintenance Program Guidelines", DNA 5449F; D194-20012-1. Boeing Aerospace Company, Seattle, Washington. 15 September 1980. (U)

Scope/Abstract: This report provides guidelines for developing a protection assurance surveillance and maintenance (PASM) program for NATO command, control and communication installations. The guidelines define the tasks and activities necessary to provide and maintain a C^3 installation protected against EMP. Once implemented, the PASM program provides confidence that a NATO C^3 installation is survivable to an EMP threat throughout its operational lifetime.

Evaluation: Useful.

23. David R.L. Worthington, "ADEPT (Adaptive Electromagnetic Predictive Technique)." DNA 4284H-A-8; SRI Project 7230. SRI International, Menlo Park, California. 1 September 1980 (U).

Scope/Abstract: ADEPT--an element assessment technique for class-sized EMP hardness predictions was developed for APACHE to access microwave elements in PACOM. EMP prediction models were formulated by weighting combinations of site physical features to best fit PRESTO assessment data. These models can be used for a first order assessment of other microwave elements using site furnished parameters. Error estimates are made for the predictions.

Evaluation: Useful.

24. M. J. Dudash, "Nuclear Weapons Effects Computer Code Catalog. Supplement 1." DNA 4614F, Supplement 1. Kaman - Tempo, Santa Barbara, California. 1 July 1980 (C).

Scope/Abstract: This document is prepared as a supplement to DNA 4614F, Nuclear Weapons Effects Code Catalog. It consists of one-page summary forms describing nuclear weapons effects computer codes.

Evaluation: Useful.

25. C. B. Gabbard and R. E. LeLevier, "Emerging High Frequency (HF) and Related Radio Communications Concepts for Enduring C^3I Roles in a Nuclear War Environment: Critical Issues in Nuclear Weapons Effects on Propagation." DNA 5551T; RDA TR-113212-001. R&D Associates, Marina Del Rey, California. 1 June 1980 (SFRD).

Scope/Abstract: This document provides a brief summary of the key points concerning the sensitivities of selective strategic C^3 concepts to nuclear weapon effects on propagation. This document is intended to assist DOD decision makers in understanding and evaluating the potential endurance and performance of selected emerging ground and airborne strategic communications systems that would operate in the medium to ultra high frequency radio bands in a general nuclear war. The book is divided into five chapters with the following chapter headings: 1) Introduction and Summary; 2) An Empirical Perspective on HF Skywave and Related Propagation Degradation in a Nuclear Environment (by LeLevier and Gabbard); 3) Review of Phenomenology and Predictive Capability in HF SKywave Communications (by D. Nielson and E. Baumann); 4) HF Skywave Communications Role in the Nuclear Environment, (by W. Jaye); and 5) Low Data Rate Groundwave Communications (by C. Crane).

Comment: This document summarizes the nuclear weapons effects on propagation issues that must be considered in judging the overall nuclear effects vulnerability of selected strategic C^3 concepts envisioned to provide enduring C^3I support in nuclear war. This document focuses on the propagation of effects in bands ranging from MF to UHF with emphasis on HF skywave propagation during and after periods of nuclear conflict. The report is composed of short contributions from selected experts in the field of nuclear propagation effects, from RDA, SRI and Rand, and is intended to provide a guide for those who have to make system procurement decisions in a complex specialized critical area.

Evaluation: Especially valuable.

26. R. Viola, S. Mercurio and J. Stangel, "Hardened Face Study Program." SG-4253-1190, Sperry Gyroscope, Great Neck, New York, June 1980. (S). AD-C022464.

Scope/Abstract: This final report presents the design and test results of a hardened radar antenna element and subarray. The testing included combined electrical, RF, and thermal tests at the French Solar Furnace. The measured results indicated minimal insertion loss degradation during the thermal pulse and a rapid recovery to original performance levels.

Comment: The report describes the development of a hardened X-Band antenna. A description of the antenna design as well as testing is provided.

Evaluation: Useful.

27. R. A. Greenwell, "Use of Electro-Optic Techniques to Achieve Electromagnetic Pulse Hardness", NOSC TR 564, June 1980. (U) AD-A089850.

Ecope/Abstract: Fiber optics will reduce the susceptibility of systems to a direct EMP threat. Cables shorter than ten meters present a tradeoff between the shielding effectiveness of standard cables and that of shielding around critical fibers optic receiver components. Long haul ground systems require only electronics protection. The fiber optic cable is immune to EMP pickup and need not be buried for protection. Fiber optic susceptibility is less than that of hardware to burnout and upset systems that allow an outage time of 1 ms. In a steady state or low dose rate environment, system vulnerability levels depend on fiber response and design margin. A fiber optic interface is feasible which will not fail under the dose levels and total dose rates equivalent to a natural space environment of 2×10^{-3} rads (Si)/sec for seven years.

Comment: This report provides general information on fiber optic systems in comparison with the normal shielded cable systems. In addition, a reasonably large number of references are provided, 70 in total, which would indicate a good basis making estimates of fibre optic systems. The primary application, however, is to satellites.

Evaluation: Useful in limited areas.

28. W. F. Moler and R. A. Pappert, "Effects of Ionospheric Reflection Height and Gound Wave Conductivity on Earth-Ionosphere Waveguide Mode and Groundwave Attenuation Rates", NOSC TR 561. Naval Ocean Systems Command, San Diego, Cal. June 1980 (U).

Scope/Abstract: A surviving ground wave signal has previously been assumed to represent the minimum expected for VLF and LF systems operating in a severely disturbed environment. The authors show that for propagation over poorly conducting soil and over a depressed ionosphere, path losses may markedly exceed those predicted by normal ground wave attenuation rates. This is shown to be caused by the invasion of the ionosphere into the presupposed free space region of the diffraction mode of groundwave duct. Because of inherent uncertainties in the ground wave model for some propagation conditions, the authors recommend that estimates of system performance in severe environments be based on earth ionospheric waveguide mode computational models.

Comment: The assumption that LF communication systems designed to operate at groundwave signal levels will maintain connectivity in a severe nuclear environment is safe only for propagation over relatively highly conductive ground. At the lower VLF frequencies the assumption is never safe. LF systems designed to operate on groundwave propagation over highly conductive ground should have a considerable system margin. For LF propagation over poorly conducting ground or freshwater ice losses may considerably exceed groundwave losses when the ionosphere is moderately depressed. When the DNA working group recommended that LF systems be designed on the basis of the surviving ground wave it was recognized that methods for calculating LF propagation in the propagation environment were inadequate. Today, although we still have questions regarding some of the air chemistry, there is little doubt that severe disturbances can be modeled with good confidence. In addition, we no longer rely on "wavehop" methods with the attendant inaccuracies for severely disturbed ionospheres for calculating LF propagation parameters. Waveguide mode propagation prediction methods work well to at least 100 kHz. Because of the possible errors and misconceptions which may arise by using the groundwave computation for estimating LF coverage in severely disturbed environments, it seems far safer to do a complete propagation analysis of coverage by means of a numerical method based on waveguide mode theory.

Evaluation: Esepcially valuable.

29. "EMP Vulnerability of Telecommunication Facilities and their Relevance to EMP Protection Standards". NCS TIB 80-3, National Communication System, Washington, D.C. June 1980 (U) AD-A089772.

Scope/Abstract: This report identifies the electromagnetic pulse (EMP) vulnerabilities of both leased and government owned telecommunication facilities in two categories, manned and unmanned stations. The major task was to identify the specific components, equipment, and facility design practices that accounted for the vulnerabilities and to determine the reasons for any difference among the categories. The information presented was extracted and summarized from unclassified government reports and data files. The primary purpose of this effort was to identify potential design practices and design practice programs that could lead to the development of federal standards for the design, installation, and maintenance of telecommunication facilities.

Evaluation: Useful in limited areas.

30. John M. Calligeros, John P. Walsh, and Raff P. Yeghiayar, "Structural Modeling and Response of Command, Control and Communication Shelter Systems for event DICE THROW." Kaman Avidyne, Burlington, Maine. March 1980. AD-A085759 (U).

Scope/Abstract: Structural Finite Elements Models of the Army Command and Control Communications Systems ANTRC-117, ANTRC-110, ANTCC-61, which utilize the S-280 shelter, and the ANTRC-145 and ANGRC-142B, which utilize the S-250 shelter, were developed for NASTRAN. Loading models and dynamic response for overpressure levels experienced in the recent Dice Throw field tests were determined for all but the ANGRC-142B. Comparisons between measured and analytic accelerations are given for the ANTRC-117 and the ANTRC-145 at an overpressure level of 41.4 kilopascals. These were generally poor for the ANTRC-117 but much more favorable for the ANTRC-145.

Evaluation: Of little value to Sentry.

Comment: The Design Handbook for TREE is the primary technical reference for analysts and designers interested in nuclear radiation effects on electronics. The handbook is published as eleven chapters, each of which may be ordered separately. Four of the chapters (Chaps. 3, 4, 8 and 9) are still in publication. The eleven chapters making up the handbook are:

Chapter	DNA #	AD Number	Title	Classification
1	1420H-1	C-020622	Introduction	Confidential
2	1420H-2	C-020623	Nuclear Burst Environment	Secret
3	1420H-3	-	Evaluation of Existing Designs and Equipment	To be issued
4	1420H-4	-	Techniques of Hardened Circuit Design	To be issued
5	1420H-5	C-020624	Hardened Component, Sub-System, and System Design	Confidential
6	1420H-6	C-020625	Design Testing (Experimental Validation)	Confidential
7	1420H-7	C-020626	Hardness Assurance	Confidential
8	1420H-8	-	Component Response Data	To be issued
9	1420H-9	-	Ancillary Equipment and Devices	To be issued
10	1420H-10	C-0200627	Radiation Interaction	Confidential
11	1420H-11	C-020628	System Generated Electromagnetic Pulse	Confidential

Evaluation: Especially valuable.

60. R. H. Christian, "Nuclear Dust Effects on Electromagnetic Wave Propagation. Volume I - Phenomenology Impact of Massive Laydowns." DNA 4776F-1. Mission Research, Santa Barbara, California. 30 November 1978. (C) AD-C019336.

Abstract: The ability to predict the deleterious effects of nuclear explosion produced dust clouds on the propagation of electromagnetic signals is assessed. Volume I addresses the state of the art of

tation and maintenance of computer codes for predicting the nuclear environments and the response of BMD systems to these environments. Uncertainties in the nuclear weapons environments have been explored by testing the nuclear effects models implemented on the BMD Advanced Research Center (ARC) computers. Supporting analysis were carried out in a number of areas including the effect of high overpressure environments on ground facilities and the transport of thermal radiation through dust clouds. A nuclear effects code library was maintained and augmented. The sensitivity of the HIT and PROBE constructs to nuclear effects was also investigated.

Evaluation: Useful.

58. Morris Campi, "Survey and Review of Aperture Shielding for EMP/RFI Fields", HDL-TM-78-25, Harry Diamond Laboratories, Adelphi, MD, December 1978 (Unclassified).

Scope/Abstract: Apertures or openings in shielding structures compromise the effectiveness of the shielding and integrity of enclosed environments unless they are treated properly. This report details the various practices and applications designed to alleviate or at least reduce the degradation resulting from either designed or unintentional apertures. Typical openings such as doorways, ventilators, equipment panels, exhaust and intake holes, and defects occurring in seams and weld joints are discussed. The analysis, practices, and guidance for electro-magnetic pulse (EMP) protection offered are consistent with those generally employed for radio frequency interference (RFI).

Evaluation: Useful.

59. M.A. Espig, Editor, "Design Handbook for TREE." DNA 1420H-1 to DNA 1420H-11. General Electric - Tempo, Santa Barbara, Cal. December 1978 (C).

Scope/Abstract: This handbook contains guidelines and data which will be useful to the design engineer when designing electronic systems for survival in a nuclear burst environment. Areas covered in the 12 chapters are the nuclear environment, evaluation of equipment, circuit hardening, system hardening, design tests, hardness assurance, component response data, interaction of transient radiation with matter, and SGEMP. This handbook is concerned primarily with application of hardened electronic devices in hardened circuit design. Physical principles and their application in the development of state-of-the-art devices are included only as required for a better understanding of the data.

enhanced ionization is a strong function of the debris altitude which is generally increased relative to any individual burst by hydrodynamic interaction between closely spaced bursts. (3) Ground wave HF communications can be degraded by the scattering produced by nuclear craters, especially when the crater size approximates a wavelength. The effects of the individual craters are small, however, the scattering from each of the large number of craters along the propagation path will add in phase. The total effect can be significant and should be considered in the selection of the frequency to be used.

Comment: This report describes the effects that are of concern in a multiple burst attack on MX dense basing. A good discussion is provided of the phenomena that occur and analysis is made of the propagation through the resulting clouds and debris. Three general areas are (1) scintillation due to dust. (2) Hydrodynamics phenomenology problems relevant to HF and VHF, and (3) Effect of cratering on groundwave propagation. An appendix on crater size scaling is incorporated into this report.

Evaluation: Especially valuable.

56. L. Marin, "A Technique of Simulating the Electromagnetic Pulse Effects of the Dual-Wire Antenna on the E4", AFWL-TR-78-39. Dikewood Corp., Albuquerque, New Mexico. February 1979 (U) AD B035766.

Scope/Abstract: A possible way of simulating the electromagnetic response of the dual wire antenna on the E4 aircraft is studied. Simulation is limited to the two initial pulses on each antenna wire. Each pulse is simulated separately by discharging a capacitance through a pulse shaping network.

Evaluation: Of little value to Sentry.

57. C. A. Bjork, et al, "Nuclear Analysis and Technology Assessment. Final Report-1978. Volume 1". SAI 80-203-HU. Science Applications, Inc., Huntsville, Alabama. February 1979. (SRD) AD-C017558.

Scope/Abstract: This document is volume 1 of a two volume final summary report of the nuclear analysis and technology assessments during the time period of 19 December 1977 through 18 December 1978. The nuclear analysis and technology assessment study supports the continued development and improvement of the BMDATC Nuclear Technology data base necessary for the development of advanced BMD technology. The study encompasses the development of analytical techniques to support technology analysis study and the implemen-

Blast damage and blast wave parameters have been reported for equipment exposed on nuclear and large HE tests. The basic data should be useful for development of vulnerability prediction technique of communication and electronic equipment.

Comments: This report contains significant data on historical events, both nuclear and HE, for which data was collected. Information is provided on overpressure, static and dynamic impulse, and behavior as a function of distance away from the event. In addition the scaling factors are derived for all events. These factors are useful in determining the effects of other size events. Information is provided on the impact on equipment for communications and other purposes. This is a valuable reference of experimental data both from a historical standpoint and from actual data standpoint.

Evaluation: Useful.

54. Gary H. Price and Georgellen Smith, "A Model of Natural HF Radio Noise in Severely Disturbed Propagation Environments." DNA 4930T; SRI Project 5978. SRI International, Menlo Park, California. 31 March 1979 (U). AD-A077619.

Scope/Abstract: A model is developed that describes the impact of severe propagation losses on the natural noise environment at high frequencies.

Comment: This analysis includes lightning effects on the HF noise background.

Evaluation: Useful in limited areas.

55. R. H. Christian, D. L. Knepp, and M. A. Messier, "Communication Degradation Issues Relevant to a Massive Attack Environment". DNA 4923F. Mission Research Corp., Santa Barbara, California. 15 March 1979. (C) AD-C020115.

Scope/Abstract: Three issues relative to a communication interface produced by a large number of closely spaced surface nuclear bursts are discussed. (1) The amplitude scintillation produced by the dust cloud is calculated and compared with absorption produced by the same dust cloud. Absorption is shown to be the dominant effect in all but very unusual circumstances. (2) Long range HF communications are susceptible to absorption when the ionization of the ionispheric D layer is increased due to irradiation by enhanced gamma rays in the fission debris. The aerial extent of this

propagation at lower frequencies (an exception is attenuation caused by dust lofted into the atmosphere by surface bursts).

Prediction of weapon effects is based on nuclear tests, laboratory experiments, theoretical studies, and simulation with certain atmospheric phenomena. Reasonably high confidence predictions can be made for most effects caused by bursts detonated below about 100 km. Prediction uncertainties increase with increasing burst altitude above 100 km, but many of the effects can be bounded with moderate confidence. Predictions for interacting, multiple, high-altitude deontations are incomplete.

Comment: This handbook summarizes nuclear weapon effects on communication and navigation systems and provides information for determining if sophisticated analyses are required for system evaluation. It replaces DASA 2090 (June, 1968). The report contains a 14 page selected bibliography.

Evaluation: Especially valuable.

52. H.S. Cabayan, F.J. Deadrick and L.C. Martin, "An approach to evaluating and implementing EMP protection requirements for communication centers." UCRL-52771. Lawrence Livermore Laboratory, Livermore, California. May 1, 1979 (U).

Scope/Abstract: This short report examines the problem of protecting communication centers against the threat of high altitude EMP. Because such EMP could damage components in an unprotected facility, an approach is described so that effective hardening procedures can be designed and has implemented. Scale model and full scale testing are discussed, although little detail is given.

Comment: This report is only 15 pages long but contains good summary information.

Evaluation: Useful.

53. E. J. Bryant and J. M. Hovanec, "Blast Damage to Communications Equipment - Preferred Data Base". ARBRL-CR-00397. GE-TEMPO, Santa Barbara, California. April 1979. (C) AD-C018135L.

Scope/Abstract: Blast damage to communication and other electronic equipment has been assembled and evaluated. The quality of damage descriptions and classification procedure were also discussed.

to EMP calculations done at Hawaii and the Philippines using the high-altitude EMP code CHAP.

Evaluation: Useful in limited areas.

51. Warren S. Knapp, "Summary of Communication and Navigation Systems Degradation in a Nuclear Environment." DNA 4890H; GE78TMP-22. General Electric-Tempo, Santa Barbara, Cal. 31 May 1979. (C) AD-C019334.

Scope/Abstract: Communication and navigation systems are vital for the command and control of strategic and tactical forces. Many of these systems rely on electromagnetic propagation through the atmosphere, and they can be degraded by nuclear explosions that modify the atmosphere and produce electromagnetic radiation that interferes with desired signals.

Communication and navigation systems operate over a large portion of the electromagnetic spectrum (from tens of hertz to tens of gigahertz), and depending on frequency are very differently affected by both the natural and nuclear-disturbed atmospheric environments. The spatial and temporal variations in nuclear-disturbed environments are also large, varying from a fraction of a kilometer to thousands of kilometers and from a few seconds to many hours. The analysis of system performance generally requires detailed specification of the system mission and the nuclear weapon scenario, in addition to descriptions of system geometry, frequency, modulation, etc.

Systems operating below about 30 MHz rely on the natural ionosphere for long-distance communications. They are susceptible to weapon effects, and system performance can be degraded or disrupted (generally by signal attenuation) for hours. Generally, widespread effects produced by multiple dispersed low-altitude bursts or by a few high-altitude bursts are required to disrupt system performance. Propagation below about 50 kHz is less affected than propagation at higher frequencies and is used for broadcast of low-data-rate high-priority messages.

Systems operating above 30 MHz generally use line-of-sight (LOS) propagation between transmitter and receiver terminals. Nuclear weapon effects include signal attenuation and a variety of phase effects that result in signal distortion. Typically, degradation regions affecting propagation above a few hundred megahertz are tens to hundreds of kilometers in extent, and the duration of effects is tens of seconds to tens of minutes for attenuation and from a few minutes to up to a few hours for signal distortion. Most of the propagation effects decrease with increasing frequency, so that degradation of propagation at higher frequencies generally occurs over a smaller region and is less persistent than degradation of

48. John F. Sweton, Editor, "DNA EMP (Electromagnetic Pulse) Handbook. Volume 6. Computer Codes." DNA 2114H-6. GE-Tempo, Santa Barbara, Cal. 5 July 1979. (C). AD-C019492.

Scope/Abstract: This volume of the DNA EMP Handbook contains information on the computer codes that have been developed for analysis of the EMP effects problem. Three general classes of computer codes are discussed: environment codes, coupling codes, and circuit analysis codes. Many of these codes are available to qualified users. Each code is discussed in detail to assist the user in selecting the best code for his application.

Evaluation: Especially valuable.

49. E.J. Baumann, "An Analysis of Upper HF/VHF Propagation Data Resulting from Nuclear-Induced High Altitude Ionization". DNA 5037T; MRC-R-954. Mission Research Corporation, Santa Barbara, California. 1 July 1979. (S/FRD). AD-C023299.

Scope/Abstract: The nuclear test data showing extended range upper HF/VHF propagation following certain FISHBOWL events are reviewed. The scattering mechanisms associated with the late time plume are identified as are the likely ray paths that supported the VHF propagation. Indications of our ability to predict the pertinent plume parameters and resultant propagation are given by comparing measurements with predictions.

Comment: This study is concerned with communication in 2000-5000 km links.

Evaluation: Useful.

50. R.M. Hamilton and W.A. Radasky, "An Improved High-Altitude EMP Environment Specification for the APACHE Program." DNA 4980T; MRC-N-398. Mission Research Corporation, Santa Barbara, California. 30 June 1979 (SRD). AD-C022004.

Scope/Abstract: This note examines the accuracy of the high-altitude EMP curve fit equations developed by Boeing for use in the APACHE program. A new specification is given which corresponds to worst case bomb and geometry considerations, and a method to obtain the vector components of the electric field is shown. The new specification and the Boeing fit equations are compared graphically

or just below the surface. The properties of tubular, tape wound, and braided wire shields are presented and the relation between the shield current and the internal voltage current are given. Some properties of multiconductor transmission lines are discussed in the final section of the report.

Evaluation: Especially valuable.

45. John F. Sweton, Editor, DNA EMP (Electromagnetic Pulse) Handbook. Volume 3. Component Response and Test Methods." DNA 2114-3. GE-Tempo, Santa Barbara, Cal. 5 July 1979. (C). AD-C019489.

Scope/Abstract: Volume 3 of this Handbook contains information necessary for experimentally assessing the EMP susceptibility of electronic equipment and components. Methods are presented for reevaluating component damage and system upset. Test methods and techniques are discussed for performing full-scale system tests and the analysis of EMP test data.

Evaluation: Especially valuable.

46. John F. Sweton, Editor, "DNA EMP (Electromagnetic Pulse) Handbook. Volume 4. Environment and Applications". DNA 2114H-4. GE-Tempo, Santa Barbara, Cal. 5 July 1979 (C). AD-C019490.

Scope/Abstract: This volume of the DNA EMP Handbook contains information on the nuclear-induced EMP environment, coupling of EMP to systems (missiles and aircraft) in flight, and system generated EMP (SGEMP).

Evaluation: Especially valuable.

47. John F. Sweton, Editor, "DNA EMP (Electromagnetic Pulse) Handbook." Volume 5. Resources." DNA 2114H-5. GE-Tempo, Santa Barbara, Cal. 5 July 1979. (C)

Scope/Abstract: Nearly 3,400 citations are given for such topics as theoretical calculations and nuclear test data related to the EMP environment and detection, EMP vulnerability analysis for systems and components, EMP protection, System Generated EMP, Source Region EMP, test direction and planning, and EMP simulators, sensors, and instrumentation.

Evaluation: Especially valuable.

42. "EMP Assessment Methodology Program. EMP Vulnerability Assessments Using PRESTO Computer Code." DNA 5069F; D194-10104-2. Boeing Aerospace, Seattle, Washington. 30 September 1979 (U) AD-B056962.

Scope/Abstract: This document describes three types of methodologies to conduct an EMP assessment of communication facilities. Each methodology describes how to gather, process and develop the necessary data to make a meaningful EMP assessment. The PRESTO computer code is used in each assessment methodology to calculate critical equipment responses in a specified nuclear EMP environment. The PRESTO program is an efficient and easy to use computer program that has been developed to assist analysts, evaluate complex electronic communication systems. Hardening analysis is used in each assessment methodology to develop means to improve the hardness characteristics of the critical equipment predicted to be vulnerable to the specified nuclear EMP environment.

Evaluation: Useful.

43. John F. Sweton, Editor, "DNA EMP (Electromagnetic Pulse) Handbook. Volume 1. Design Principles." DNA 2114H-1. General Electric-Tempo, Santa Barbara, Calif. 5 July 1979 (C). AD-C019488.

Scope/Abstract: This report is the first of a six volume set on nuclear electromagnetic pulse. This series of reports covers all aspects of EMP and its effect on military systems. This initial volume describes equipment design principles for hardening to EMP. This series replaces a prior set of EMP Handbooks dated November 1971.

Comment: The DNA EMP Handbook is the primary technical reference for EMP analysis and investigators.

Evaluation: Especially valuable.

44. John F. Sweton, Editor, "DNA EMP (Electromagnetic Pulse) Handbook. Volume 2 - Coupling Analysis," DNA 2114H-2, GE Tempo, Santa Barbara, California, 5 July 1979. (C) AD-C019587.

Scope/Abstract: Formulas for calculating the currents and voltages induced in cables by the electromagnetic pulse (EMP) are presented. The electromagnetic fields near a finitely conducting surface (the soil) are calculated and the formulas are given for calculating the current and the voltage induced in long conductors just above, at,

Satellite Communications System; 3) Increasing System Survivability by Operational Procedures; 4) Apache NAVCAMS EASTPAC EMP Hardening Program; 5) Missile Guidance and Control EMP/SGEMP tradeoffs; 6) EMP Shielding Specification Considerations for Ground Base Facilities; 7) Shield Topology Concepts Applied by System Hardening; 8) Differences between EMI and EMP Grounding Practices.

Evaluation: Useful.

40. "EMP Assessment Methodology Program EMP. Vulnerability Assessment Using Abbreviated Electromagnetic Analysis Techniques." DNA 5076H; D194-10104-3. Boeing Aerospace, Seattle, Washington. 15 October 1979 (U).

Scope/Abstract: This handbook presents a methodology developed under DNA sponsored programs for performing EMP assessments of communication facilities. This methodology has proven to be a useful engineering tool for predicting the effects of nuclear EMP environments on communication facilities and for defining hardening modifications to assure continued operation in that environment.

Evaluation: Especially valuable.

41. Louis J. Belliveau, Stanley Bukalski, Rosalie W. Hine and John A. Rosado, "Collateral Nuclear Weapons Effects on Airborne Platforms used by the Minimum Essential Emergency Communications Network". HDL-SR-79-7. Harry Diamond Labs, Adelphi, Maryland, September 1979. (C) AD-C020374L.

Scope/Abstract: This report discusses the effect on an aircraft of a nuclear burst.

Comment: There are a large number of reports dealing with nuclear effects on aircraft. A good general source is, "Handbook for Analysis of Nuclear Weapon Effects on Aircraft," DNA 2048H-1 and 2. Kaman Airdyne, Burlington, Mass. 18 March 1976 (U).

Evaluation: Useful in limited areas.

37. "EMP Assessment Methodology Program, EMP Vulnerability/Hardening Guide for C^4 Elements", DNA 5122T; D194-10104-4. Boeing Aerospace Company, Seattle, Washington, 30 November 1979. (U)

Scope/Abstract: A vulnerability/hardening guide for PACOM C^4 type elements was developed. The guide provides assistance in identifying key element features which imply a near certain vulnerability to EMP. Once identified, appropriate hardening fixes can be implemented using hardening recommendations, EMP transient specification, and bonding and assembling instructions which are included as a part of the guide. The key element features were identified from a study of 60 previously assessed elements. These key features, typical equipment configurations, and the effectiveness of various hardening fixes were evaluated using PRESTO computer models.

Comment: A good general reference for understanding the practical methods for hardening command, control, communication and computer hardware to EMP.

Evaluation: Especially valuable.

38. I. N. Mindel & B. J. Ryan, "DNA System EMP Hardening Symposium, Vol. 1," DNA 5139P-1. IIT Research, Chicago, Illinois. November 1979. (S) AD-C025541.

Scope/Abstract: These Proceedings present papers give at the DNA Systems EMP Hardening Symposium, 7-9 August, 1979, at the Naval Ocean Systems Center, San Diego, CA.

Comment: A variety of papers on EMP and related problems.

Evaluation: Useful.

39. I. N. Mindel, and B. J. Ryan editors, "DNA System EMP Hardening Symposium," Vol. II, DNA 5139P-2, ITT Research Institute, 1 November 1979. (S). AD-C024858.

Scope/Abstract: These proceedings depict the state-of-the-art for system protection and assessment as presented at the DNA system EMP Hardening Symposium, 7-9 August 1979, at the Naval Ocean Systems Center, San Diego, CA.

Papers include: 1) Retrofitting EMP Harness; 2) High-Altitude Electromagnetic Pulse (HEMP) Hardening Designs for the Defense

35. Burt Gambill, "An Assessment of Requirements for Computer Models of Communication Link Performance in a Nuclear Environment, Vol II, Special Requirements for Multilink, Multiburst Simulation Codes." DNA 5151T-2; GE79TMP-68-Vol-2. GE-TEMPO, Santa Barbara, California. 31 December 1979. (S) AD C024451.

Scope/Abstract: These reports describe the general requirements for models to meet the needs of simulation. A general description of the reason for modeling each of the effects as well as a discussion of the type of modeling requirements is presented. In addition, each of the physical modules is described and comparison is made between existing model assumptions.

Comment: These two reports provide excellent background material on the generic nuclear effects problems as well as a brief description of available codes.

Evaluation: Especially valuable.

36. Gordon J. Fulks, "HF/VHF Propagation in a Nuclear Environment: Bomb Mode Phenomenology." DNA 5201F; MRC-R-455. Mission Research Corp., Santa Barbara, Cal. 1 Dec. 1979 (S/FRD) AD-C028252.

Scope/Abstract: HF/VHF radio propagation off of the plume created by a high altitude nuclear explosion is examined. This paper defines the nature of the plume and then discusses radio propagation off that plume. Numerous barium cloud experiments provide additional insight. Finally, utilization of bomb modes is considered. More specifically, this paper discusses basic plume phenomenology from the origins of plume ionization to motion and structuring of the plume to plume density and size. Because the details of plume structure are important to bomb mode communication, the detailed structure of the bottom of the plume is considered including the shape of a striation end. Various propagation modes are examined and estimates of scattering cross sections made. Data from various barium cloud experiments provides valuable insight into both plume phenomenology and bomb mode propagation. System applications of bomb modes are also discussed.

Evaluation: Useful.

33. R. J. Jordano, R. R. Rutherford and B. Gambill, "Statistical Representation of Nuclear Effects Uncertainties" (U), DNA 5202F, GE80TMP-4, General Electric Company-TEMPO, Santa Barbara, California. 1 January 1980 (C/FRD). AD-C026876.

Scope/Abstract: Methods are investigated for developing a statistical representation of the uncertainty in the calculated results of DNA nuclear effects computer models. The principal technique demonstrated is that of estimating uncertainty distributions for key model parameters, then using a translation of variables to propagate these uncertainties through the model "function" to obtain an uncertainty distribution for the computed model output. The technique is demonstrated by showing the effects of uncertain dispersal of radioactive fission debris on VLF signal propagation. Uncertainty probability distributions are computed for the received VLF signal strength in the presence of an atmospheric nuclear detonation. Special problems associated with extending single-link results to communication network analysis are addressed.

Evaluation: Especially valuable.

34. W. S. Knapp and E. J. Feniler, "An Assessment of Requirements for a Computer Model of Communicaion Link Performance in a Nuclear Environment: Volume 1, General Requirements and Engineering Link Vulnerability Codes." DNA 5151T-1; GE79TMP-68-Vol-1. GE TEMPO, Santa Barbara, California. 31 December 1979. (C) AD C024450.

Scope/Abstract: This report describes requirements for computer modeling of communication link performance in nuclear environments. Volume 1 of the report describes general requirments and specific requirements for engineering link vulnerability codes. Volume II describes requirements for multilink, multiburst simulation codes.

Evaluation: Especially valuable.

31. Charles L. Rino, "Propagation Modeling and Evaluation of Communication System Performance in Nuclear Environments", DNA 5265F, SRI International, Menlo Park, California. February 1980 (U).

Scope/Abstract: This report summarizes propagation modeling work for predicting communications system performance in disturbed nuclear environments. Simple formulas are developed that characterize the onset of scintillation, the coherence time of the scintillation, the coherence bandwidth loss and the associated delayed jitter plus the angle of arrival scintillation for radar applications.

The calculations are based on a power law phase screen model and they fully accommodate a varying spectral index and arbitrary propagation angles relative to the principal irregularity axis. In a power law environment, the signal structure is critically dependent on the power law index, particularly under strong scatter conditions.

Comment: This report provides a theoretical basis for modeling of signal propagation through a random atmosphere or a random cloud and provides the basic theory plus additional references to other theories and parallel work.

Evaluation: Useful.

32. Allen H. Michelet, "Performance of an Adaptive HF/VHF Communication System Concept in Disturbed Propagation Conditions", DNA 5257F; MRC-R-547. Mission Research, Santa Barbara, California. 1 February 1980 (S).

Scope/Abstract: An adaptive HF/VHF communication systems concept has been proposed by the Electrophysics Laboratory of the Avionics Division of ITT. The system concept is designed to provide Minimum Essential Emergency Communications Network (MEECN) connectivity among key elements of the worldwide military command and control system. This report describes the development and application of a digital modem simulation of the proposed system concept. Simulation is used to determine the sensitivity of the system performance to variations in modem design and decision thresholds and to measure performance of the system operating in a variety of possible nuclear and nonnuclear environments.

Evaluation: Useful.

prediction capabilities for the dust environment with emphasis on the massive attack scenario as it would occur in an attack of a strategic missile launch complex. Burst interactions that alter the single burst results are discussed. Several effects that invalidate a simple linear summation of single burst results are identified. No effects were found that will increase the dust lofted per megaton of yield. However, the dust distribution of the maximum concentration at some locations can be increased over that predicted for a single burst. No simple theory nor models currently exist to treat this problem. Several detailed numerical calculations are suggested that would further our understanding of the various possible multiple burst interactions.

Summary: This report provides a review of the phenomenology that occurs in a massive attack. The physical behavior that occurs is described and the current capability to predict the specific conditions are reviewed. The emphasis is on dust production and the fireball behavior that will influence the dust loading and distribution in the atmosphere.

Evaluation: Especially valuable.

61. S. L. Gutsche, "Nuclear Dust Effects on Electromagnetic Wave Propagation. Volume II, Estimations of Effects from 1 MHz to 100 GHz", DNA 4776F-2. Mission Research, Santa Barbara, California. 30 November 1978. (C) AD C019337.

Scope/Abstract: The effects of dust clouds produced by a 1 megaton surface burst on electromagnetic wave propagation are addressed. The primary effect considered is single attenuation produced by scattering as well as dust particle heating or absorption. Attenuation effects as a function of frequency over the range 1 MHz to 100 GHz are estimated for generic ground-ground, ground-air, ground-space, air-air, and air-space applications by estimating nominal minimum attenuation and maximum attenuation conditions within 5 separate regions of a dust cloud including ejecta, blast, stem, main cloud and fallout. The attenuation is examined at 6 calculation times from 3 to 1000 seconds after detonation. Nominal attenuation results are supplied by a parameter study which shows the effects of specific dust environment uncertainties on predicted attenuation levels. The nuclear dust produced effects are then compared with degradation levels caused by naturally occurring weather effects such as rain and fog. Secondary propagation effects such as phase shift and scintillation, refraction, and pulse shape distortion are only discussed briefly.

Summary: This report summarizes the effects of 1 MT surface blast on communication over a wide range of frequencies. It provides a basis for evaluating the effects of dust on communications in the post attack environment.

Evaluation: Especially valuable.

62. D.R. McDaniel, "Proceedings of the DNA/LASL High-Altitude Nuclear Weapons Effects Summer Study. Volume I - Executive Summary." DNA 4736P-2; SRI Project 4960. SRI International, Menlo Park, California. 1 November 1978 (C). AD-C020803

Scope/Abstract: A High-Altitude Nuclear Weapons Effects Summer Study was held at Los Alamos, New Mexico, during the period 9-25 August 1978. The study was jointly sponsored by the Defense Nuclear Agency and the Los Alamos Scientific Laboratory.

The Study Group reviewed the current state of understanding of high-altitude nuclear effects phenomenology and the propagation of electromagnetic waves through disturbed environments debris. Further, they recommended experimental programs designed to resolve some of the uncertainties existing in nuclear phenomenology. In addition, a Working Group considered the problem of mitigation of deleterious effects on communications caused by structured ionospheric plasmas. Finally, the status of phenomenology and propagation models was reviewed, along with the various system codes they input. These models and codes are listed and described.

Comment: The other two volumes in this series are: 1) D. R. McDaniel, "Proceedings of the DNA/LASL High-Altitude Nuclear Weapons Effects Summer Study. Volume 2 - Working Group Reports." DNA 4736P-3; SRI Project 4960. SRI International, Menlo Park, Cal. 1 November 1978. (S). AD-C021442. 2) L. A. Wittwer and R. L. Bogush, "Satellite C^3 Nuclear Mitigation Techniques. Vol. 1, Summary from DNA/LASL High Altitude Nuclear Weapons Effects Summer Study." DNA 4736P-1. Defense Nuclear Agency, Washington, D.C. 1 Nov. 1978. (C) AD-C017112.

Evaluation: Useful.

63. Allen H. Michelet and Mark R. Frolli, "Modeling and Initial Performance Evaluation of the Proposed MEECN Adaptive HF/VHF Communication System Concept." DNA 4762T; MRC-R-411. Mission Research Corp., Santa Barbara, California, Nov. 1978. (S). AD-C022812

Scope/Abstract: This report describes the development and initial application of models designed to aid in evaluating the performance of a specific adaptive HF/VHF communication system concept operating in a disturbed propagation environment. Emphasis is placed on critical elements of the receiver, particularly in the areas of signal processing, signal detection and digital data processing. Some preliminary error rate comparisons are provided which indicate the relative effects of different signal, system design and threshold logic parameters on system performance.

Comment: Included in the report are listings of short programs that could be useful for HF/VHF C^3 estimates.

Evaluation: Useful.

64. Morris Campi, "Survey and Review of Building Shielding to Electromagnetic Waves from EMP", HDL-TM-78-23, Harry Diamond Laboratories, Adelphi, MD., November 1978 (U). AD-B034726L.

Scope/Abstract: The electromagnetic shielding characteristics of communications-type facilities for commercial and government installations in CONUS are reviewed. A survey of shielding behavior of structures and materials, along with calculations of shielding effectiveness are introduced to familiarize the reader and to enable an evaluation of facility susceptibility to electromagnetic fields.

Evaluation: Useful in limited areas.

65. James H. Thompson, "Dust Cloud Modeling and Propagation Effects for Radar and Communications Codes", DNA 4697T, GE78TMP-81, General Electric Company-TEMPO, Santa Barbara, California. 1 November 1978 (U). AD-A071368.

Scope/Abstract: This report describes new and improved models for dust generated by a low-altitude nuclear burst and the effects of this dust on radar and communications propagation. These models were developed for the WEPH code and are applicable for use in radar or communication codes. Developed in this report are:

- o An improved Mie calculation,
- o An extended model of the dust particle size distributions,
- o Methods for calculating the complex index of refraction for dust particles,
- o Dust models for the nuclear stem and pedestal regions.

Evaluation: Useful.

66. R. Viola, S. Mercurio and J. Stangel, "Hardened Face Study Program." SG-4253-1072. Sperry Gyroscope, Great Neck, New York. August 1978 (S). AD-C015460

Scope/Abstract: This interim report presents the theoretical design of a hardened antenna element and subarray. Included are verification tests and measurements for the electrical and thermal design.

Evaluation: Useful in limited areas.

67. Jack E. Bridges and Dr. Sherwin R. Kahn, "System Impact of Obscure Cable Pickup Mechanisms." DNA 4690F; IITRI-E6413. IIT Research Institute, Chicago, Illinois. July 1978 (SRD). AD-C019073L.

Scope/Abstract: The system impact of obscure cable pickup mechanisms, such as axial magnetic EMP field penetration into long landline buried communication cables, was assessed on a worst-case basis. The axial magnetic EMP pickup may become important where some of the cables in a shielded multi-conductor cable are spiraled around a core of other cables which contain ferromagnetic materials. This forms, in effect, a giant solenoid many miles long containing a ferromagnetic core. Possible system impacts from the obscure mechanisms tend to introduce new forms of degradation rather than augmenting previously known failure tendencies. Obscure mechanisms can become the dominant EMP pickup where classical penetration mechanisms are suppressed or where very high EMP magnetic fields appear in the intermediate time regimes.

Evaluation: Useful.

68. Michael McKay and John Ozeroff, "Nuclear Weapons Effects Computer Code Catalog". DNA 4614F. Jaycor, Del Mar, California. 1 July 1978 (C).

Scope/Abstract: A collection of one-page summary forms each describing a DNA-sponsored computer code.

Evaluation: Useful.

69. Gerald K. Schlegal, "Hardened Alternative Means of Communications." AFWL-TR-77-114. R&D Associates, Marina Del Rey, Cal. June 1978. (S) AD-C0165046.

Scope/Abstract: This report describes two alternative strategic communications link concepts: a rocket relay system (RRS) and a rocket launched balloon system (RLBS).

Comment: This study includes consideration of specific radio hardware operating within line-of-sight constraints from high altitudes. Network connectivity was analyzed with the NETSIM program. Background information was obtained from a number of references, including the following:

1. "Dynamic Communications Network Simulator, NETSIM," TR75-1. U.S. Air Force Academy, January 1975. (U)

2. "Rocket Launched Balloon System - Volume I, System Characteristics; Volume II, Analysis, Tradeoff Studies, and Support Data." AFWL-TR-76-1. Air Force Weapons Lab, Kirtland Air Force Base, N.M. April 1977 (SRD).

3. "Rocket Relay System Preliminary Definition." AFWL-TR-75-90. Air Force Weapons Lab, Kirtland AFB, N.M. May 1977 (SRD).

4. "Nuclear Effects on Ultra High Frequency Propagation for AFWL Command and Control Communications (C^3) Alternate Concepts." AFWL-TR-75-0089. Air Force Weapons Lab, Kirtland AFB, N.M., January 1975 (SRD).

5. "SFLCS PCL Performance Evaluation." RDA-TR-6633-003. R&D Associates, Marina Del Rey, Cal. Nov. 1976 (S).

Evaluation: Especially valuable.

70. L. L. Bailin, C. G. Gabbard, and F. P. Kaiser, "The Feasibility of an Air Force High-Frequency Groundwave Network in the Continental United States", AFWL-TR-76-287, R&D Associates, Marina Del Rey, California. June 1978. AD C016589L (S).

Scope/Abstract: This study examines the feasibility of constructing a high-frequency groundwave communications network using existing high-frequency sites in the continental U.S. More specifically a case study of Air Force high-frequency sites is examined and the hardware upgrades required at selected sites to provide a baseline network capable of supporting strategic missions are outlined.

Comment: This report reviews the problem of skywave HF communication in a nuclear environment. A proposed HF groundwave methodology is also described. Attenuation of groundwave signals as a function of distance is given and simplified models of expected signals as a function of distance from the transmitter are produced. A potential linkage of sites and the cost associated with the system are discussed. Some discussion of noise is also presented.

Evaluation: Useful.

71. Stanley Kronenberg, Harry L. Berkowitz, Robert A. Lux, Robert L. Pfeffer, Vincent Rosati and Harry Van Gorden, "Nuclear Radiation Vulnerability of Proposed Army Fiber Optics Communication Systems." DELET-TR-78-13. Electronic Materials Research Division, US Army Electronics Technology & Devices Laboratory, Fort Monmouth, New Jersey. June 1978 (U). AD-803516L

Scope/Abstract: Components which are likely to be used in Army tactical communication systems were investigated for their radiation hardness both at facilities simulating the prompt initial radiation from nuclear weapons and in steady state radiation simulating the fallout environment. Transmitters and receivers of light pulses were found to be sufficiently hard to meet Army requirements; two fiber optics links were found to suffer serious radiation-induced attenuation. Significant unforeseen effects were found which make the control of fiber optics behavior in a nuclear environment impossible at this time.

Comment: More recent reports have updated the data presented here.

Evaluation: Ueful in limited areas.

72. Allen H. Michelet, Warren A. Schlueter and Mark R. Frolli, "A Preliminary Investigation of a Specific HF/VHF Communication System Concept." DNA 4367T-2; MRC-R-374. Mission Research Corporation, Santa Barbara, California. 15 June 1978 (S). AD-C020396

Scope/Abstract: This report describes the initial phase of the application of a system evaluation methodology designed to aid in assessing the performance of a specific HF/VHF communication system concept operating on signals transmitted through a nuclear disturbed propagation environment. Three key technologies must be addressed in this type of system performance evaluation. These are: prediction of the nuclear burst phenomenology and how it affects the propagation environment; analysis and prediction of the effects of the disturbances on radio waves propagating through the environment, and a determination of the response of the communication system to degraded signals. The system evaluation approach, therefore, consists of four discrete steps; system performance analysis, receiver response analysis, propagation analysis, and environmental description.

A number of general and specific schemes have been suggested as capable of improving the performance of HF/VHF communication systems operating in a nuclear environment. From these, one particular concept has been selected for evaluation. This concept is first described in terms of system characteristics and operation, and then considered from the viewpoint of system functional requirements. Initial modeling of the more important elements of the system and the initial structure of a simulation of the system are discussed, with emphasis placed on signal processing and detection, and data processing. Characteristics of the ambient, naturally disturbed and nuclear disturbed propagation environment are also generally discussed.

Evaluation: Useful.

73. Lloyd Duncan, "Prototype HEMP Design Practice Handbook." IRT 8165-012. IRT Corporation, San Diego, California. May 31, 1978 (U). AD-A056731.

Scope/Abstract: The Prototype HEMP Design Practice Handbook provides a systematic approach to protection of the DCS. The handbook is based on a generalized protection procedure which parallels the programmed development cycle of systems. This protection procedure employs the zonal characterization of facilities and utilizes nested shields, regional grounding, penetration and aperture treatments in the form of design practices as the primary protection measure. The

handbook is separated into two parts. Part 1 contains introductory material, the protection procedure and use of the protection elements. Part 2 contains appendices of detailed resources.

Evaluation: Useful in limited areas.

74. D.H. Sowle and G.J. Fulks, "Nuclear Effects on Meteor Scatter and Adaptive HF/VHF Communication Systems." DNA 4716F; MRC-R-390. Mission Research Corporation, Santa Barbara, California. 30 April 1978 (S/FRD). AD-C017535.

Scope/Abstract: Nuclear phenomena of special significance to Meteor Burst Communication Systems and Adaptive HF/VHF systems are surveyed and their likely impact on MEECN type connectivity estimated. Under assumptions which seem theoretically reasonable, it is found that scattering of VHF signals may provide connectivity for a properly designed system over a wide range of explosive conditions. A brief summary of nuclear test data revealed several observations which may be interpreted as confirmatory and none which appear to contradict the important assumptions. Meteor burst or adaptive HF systems appear especially attractive as an overlay complementary to satellite communication systems.

Evaluation: Especially valuable.

75. W. Sweeney, P. Dittmer, J. Wilon, and E. Cukawskas, "The Nuclear Weapons Effects Subroutines of the ETC^3 Code. Integrated Nuclear Assessment (INCA) Program", DNA 4351T-2A, BDM Corporation, McLean, Virginia, 14 March 1978, (C), AD C016640.

Scope/Abstract: This report consists of a brief description of the nuclear weapons effects subroutines used in the European Theater Command, Control and Communications (ETC^3) code, formerly called the INCAM code. A general description of two driver programs is also included. Particular attention is given to equations programmed and their sources, with the goal of providing documentation of the algorithms currently used in the nuclear weapons effects subroutines. Blackout routines are not included in this report.

Comment: This report describes in detail the subroutines used to calculate varying effects of nuclear weapons such as overpressure, dynamic pressure, thermal radiation, total ionizing dose, gamma dose, neutron fluences, etc. Some important references associated with this document are:

1. Defense Intelligence Agency, "Physical Vulnerability Handbook Nuclear Weapons," AP-550-1-2-69-INT. 1969, revised 1974, (C).

2. "Capabilities of Nuclear Weapons." DNA EM-1. Defense Nuclear Agency, Washington, D.C. July 1972, (SRD).

Evaluation: Useful.

76. SV&H Engineering Staff, "Data Quality/Confidence Requirements for High-Altitude EMP Assessments Using PRESTO." DNA 4284H-A-1. Boeing Aerospace Company, Seattle, Washington. 1 March 1978 (C). AD-C024969L

Scope/Abstract: This document describes the data quality confidence requirements for communications element EMP assessment and hardening which are based upon a review of APACHE assessment results and the theoretical relationships between safety margin, data quality, and survival confidence.

The APACHE element EMP assessments are reviewed to develop patterns in assessment results which can be exploited to increase the quality of the assessment data and reduce the overall cost for communications element assessment and hardening. The data quality and survival confidence relationships are quantified and discussed to show present accuracy goals. An assessment and hardening methodology is described which is based upon a generic grouping of elements having similar EMP response and which will reduce costs of EMP assessment and hardening.

Evaluation: Useful.

77. "Survivability Assessment of Command Control and Communication Facilities, Vol. 1, Land Based Systems" DCA TM 166-78. Defense Communications Agency, March 1978. (U) AD-B028619L.

Scope/Abstract: Manual procedures suitable for a preliminary assessment of the survivability of C^3 facilities under nuclear attack are presented. Uncertainty propagation and survivability calculations are handled by graphical and tabular procedures. A summary of approximate nuclear weapons effects formulas is given in the appendix. This volume considers surface and other ground facilities while underwater, airborne, and spaceborne structures will be considered in future volumes.

Comment: The primary emphasis in this document is on structural failures, however, an extensive discussion on uncertainty and survivability is given. In addition, there is some discussion of

the EMP threat. A outstanding document to understand the land based facility and the potential impacts in the nuclear environment.

Evaluation: Useful.

78. H. A. Blank, P. C. Wood, J. A. Campbell and P. W. Fox, "Integrated Nuclear Communications Assessment Data Base Evaluation", DNA 4352-1A, Computer Sciences Corp., Falls Church, Virginia, 6 January 1978. (U)

Scope/Abstract: A data base design for the INCA project is developed. The project requirements are used to develop a specification for an integrated data base system.

Comment: This report describes all of the data that would be required to make the INCA system work.

Evaluation: Useful in limited areas.

79. W. M. Cross, et al, "Project INCA VLF, LF, HF and VHF/UHF Link Assessments (U), Volume II-VLF, LF, HF, and VHF/UHF Link Performance Assessments." DNA 4353F-1F, GTE Sylvania, Inc., Electronic Systems Group, Needham, Massachusetts. 2 January 1978 (S/FRD). AD-C017188.

Scope/Abstract: The CCIS networks which operate in the VLF, LF, HF and VHF/UHF radio bands and serve the NCA, CINCLANT and CINCEUR in the Atlantic, Mediterranean, and European areas were assessed to determine their performance for benign and nuclear stressed ionospheric conditions. An ECM threat was also considered against the VLF/LF links. Each radio link was analyzed in terms of the received SNR, SJR, and CER for 80, 90, and 99 percent time availability. The WEDCOM III, DCOM, NUCOM-BREM, AM^2, WEPH-V and TROPO codes were used. Receiver performance curves for each band were derived for actual atmospheric noise statistics and modulation/ coding types.

Evaluation: Useful.

80. R. J. Jordano, R. R. Rutherford, J. H. Thompson, and B. Gambill, "Sensitivity of HF Blackout Predictions to Atmospheric Parameters," GE-TEMPO, Santa Barbara, California, Jan. 1978 (C). AD C013 407L.

Scope/Abstract: This document evaluates the sensitivity of high frequency communications system performance to variations in atmospheric parameters in order to establish the requirements for new and more accurate atmospheric measurements. Emphasis is on the performance of systems subject to nuclear induced atmospheric absorption. Engineering computer codes for high frequency systems performance calculations are surveyed to determine which nuclear phenomenology and propagation models include a correct functional dependence on atmospheric parameters. Using select models for fireball debris dynamics, gamma ray energy transport, energy deposition, atmospheric chemistry and electron collision frequencies, sensitivity analysis for realistic HF systems are conducted to determine quantitative relationships between system performance and expected variations in the basic atmospheric intrinsic parameters such as temperature, pressure and density.

Summary: This document describes the sensitivity of real atmospheric conditions on the model predictions for HF communication between hypothetical locations. A brief review of models is made with some critique of problem areas in the models. A simplified fireball rise model is included with good comparison with WEPH VI. All communications studied were over distances greater than 500 mi. Results indicate atmospheric parameters do affect the results.

Evaluation: Useful.

82. S.L. Gutsche, "Integrated Nuclear Communications Assessment (INCA): Cemetery Net Performance in an Air Defense Nuclear Environment." DNA 4353T-1B; MRC-R-356. Mission Research Corporation, Santa Barbara, California. 30 December 1977 (S/FRD). AD-C015994

Scope/Abstract: This report describes the second phase of an MRC effort in support of the Integrated Nuclear Communications Assessment (INCA) Program. Information is presented regarding an assessment of the performance of certain links of the Cemetery Net Communication system in a nuclear environment produced by air defense bursts. A brief description of the Cemetery Net is provided, including a discussion of the nodes and links of interest to the system. The air defense nuclear scenario applied to examine link performance is also discussed.

Results showing individual link performance during and after a nuclear air engagement involving several detonations are presented. Results are provided for both daytime and nighttime situations, since HF attenuation levels can change significantly with time of day. Signal absorption levels are also predicted for a single air defense detonation in the middle of the geographical region of interest. Conclusions based on the computed link attenuations are drawn.

Evaluation: Useful.

82. "EMP Penetration Handbook on Apertures/Cable Shields/Connectors/Skin Panels", AFWL-TR-77-149, Air Force Weapons Laboratory, Kirtland AFB, NM; Preparing agency: Dikewood Industries, Inc., Albuquerque, NM, December 1977 (U). AD B029585L.

Scope/Abstract: This is a highly technical handbook containing formulas and data pertinent to electromagnetic pulse (EMP) penetration through: (1) apertures, (2) cable shields, (3) connectors, and (4) skin panels.

Evaluation: Useful.

83. C.L. Stansberry, "EMP, Lightning, and Power Transients: Their Threat and Relationship to Future EMP Standards." TN22-77. Defense Communications Engineering Center, Network Design and Survivability Branch, Reston, Virginia. November, 1977 (U). AD-A058404

Scope/Abstract: A general description of high-altitude EMP phenomena is given, as well as a characterization of the EMP radiated field in relation to worst-on-worst case parameters. EMP effects on electronics are compared with those of lightning, since lightning produces similar effects. Power line transients are also discussed. The use of lightning and power line transient protection specifications, with modifications, for developing EMP protection specifications is proposed.

Comment: This document is one of a series concerning Electromagnetic Pulse effects on communication systems. The Defense Communications Engineering Center prepared this document in response to tasking received from the Manager, National Communications System (NCS). The purpose of this series is to provide information on the subject of EMP effects and the vulnerability of existing communication assets of the Defense Communications System which can form

the basis for the development of Federal Telecommunication Standards by the NCS.

Evaluation: Useful in limited areas.

84. P. Fox, K. Harper, R. Aronstein, and J. Reese, "Integrated Nuclear Communications Assessment (INCA), The INCA Automated Assessment Tool", DNA 4351T-1B, Computer Sciences Corp., Falls Church, Virginia, 1 November 1977 (C), AD C025 010.

Scope/Abstract: This report describes the results of the study to determine the feasibility of integrating various computer codes into a single system called the Automated Assessment Tool (AAT). The purpose of the AAT is to assess the vulnerability and survivability of a large communications system to nuclear stress. The results of a survey of existing computer codes are presented. A top down functional design for the AAT is developed. The bottom up design matching the codes uncovered in the survey to the functions described in the top down design is presented. A system architecture for the AAT is described. Problem areas associated with the implementation of the AAT are discussed. Conclusions and recommendations concerning implementation are offered. Appendices of the report give detailed descriptions of the computer codes investigated in the computer code survey.

Comment: A good general report on integration of the capabilities of several codes.

Evaluation: Useful.

85. Arthur Whitson and Burt Gasten, "EMP Engineering Practices Handbook", NATO File No. 1460-2, SRI International, Menlo Park, CA, October 1977 (U), AD-B02632L.

Scope/Abstract: This handbook is intended for use by NATO as the primary guidance reference in designing EMP protection and in preparing cost estimates for such protection. EMP protection principles are presented following an approach that divides the protection problem into interference zones and into the boundaries between zones. The zoned outlined is used to present the EMP protection engineering practices. Methods to test NATO facilities and confirm that EMP protection had been incorporated are included. EMP protection costs are discussed, and examples are given.

Evaluation: Useful.

86. D.H. Sowle, "An Ambient HF Radio Mode Model." DNA 4420T; MRC-R-347. Mission Research Corporation, Santa Barbara, California. September 1977 (U). AD-A052576

Scope/Abstract: An approximate method for calculation of high frequency skywave radio propagation geometry is developed. The method is inexpensive in comparison to ray trace techniques yet capable of accounting for instantaneous local ionospheric conditions including tilt and off-great-circle propagation. It is thus appropriate for use in assessment of system response to nuclear effects of HF propagation, including alterations of mode geometry. Errors inherent in the approximations are shown to be small compared to errors caused by inaccuracies in ambient or disturbed ionospheric models.

Evaluation: Useful.

87. J.L. Heritage, J.E. Bickel and C.P. Kugel, "Meteor Burst Communication in Minimum Essential Emergency Communication Network (MEECN)". Technical Report 138. Naval Ocean Systems Center, San Diego, California. 16 August 1977 (U). AD-B023092

Scope/Abstract: This technical report is an interim report produced in concert with the DCA Command and Control Technical Center (CCTC), Naval Ocean Systems Center (NOSC), and Rome Air Development Center (RADC) personnel in support of the JCS in carrying out centralized direction management and technical test and evaluation of the Minimum Essential Emergency Communication Network (MEECN). This report is the first one to be issued which presents the results of studies and evaluation of the potential of Meteor Burst Communications (MBC) for Minimum Essential Emergency Communication Network (MEECN). The results of a ground-to-ground MBC field test investigation in MEECN environment are included. The potential of an advanced MBC system for MEECN ground-to-ground, air-to-ground, ground-to-air, and air-to-air link is extrapolated based upon field test data.

Evaluation: Useful.

understanding of the persistence of spatial distribution of the ionization of the high altitude nuclear plasma, now predictable with less confidence. Unfortunately, these are the most important effects to a communications system. Moreover, their importance to the design of future systems is strongly intertwined with threat scenario considerations. Their prediction in scenario sensitive matters is probably impossible, even though future research may reduce the late time uncertainties in nuclear effect code estimates.

Evaluation: Useful.

113. Norman J. Rudie, Principles and Techniques of Radiation Hardening, published by Western Periodicals Company, North Hollywood, CA 91605. 1976. (U)

Scope/Abstract: This is a 3-volume set discussing all radiation effects of military interest. Volume 1 addresses Interaction of Radiation with Matter and Material Effects, Volume 2 deals with Transient Radiation Effects in Electronics (TREE), and Volume 3 covers Electromagnetic Pulse (EMP) and system generated EMP. All subjects are covered in technical depth.

Evaluation: Especially valuable.

114. B. Gambill, Jr., "Design for Anticommunications Link Attack." GE75TMP-16. GE-Tempo, Santa Barbara, Cal. October 1975 (S). AD-C003590L.

Scope/Abstract: A semigraphical, semianalytical procedure is described and used to define an anticommunications link attack. Nuclear burst yield, altitude and time were determined to maximize the effects on specified LF and HF propagation links. An example attack generated by the procedures is given and the results achieved by the attack are computed and discussed.

Comment: This report examines the effect of high altitude bursts on long range strategic communications using the WRECS-IV code.

Evaluation: Useful.

112. C. H. Humphrey, C. B. Gabbard, and M. Gantsweg, "Nuclear Effects on Ultra High Frequency Propagation for AFWL Command and Control Communications (C^3) Alternative Concepts", AFWL-TR-75-89. R&D Associates, Santa Monica, California. January 1976. (S/RD) AD C004780.

Scope/Abstract: The Air Force Weapons Laboratory (AFWL) is responsible for determining the vulnerability of strategic communications systems under Air Force control and procedures which will reduce such vulnerabilities. This report examines propagation degradation of radio-frequency waves due to nuclear weapons effects for selected AFWL alternative communication system concepts.

Comment: This report reviews the problem of communication in a nuclear environment and proposes to evaluate several AFWL C^3 concepts. The major nuclear effects on propagation of HF communications are reviewed. In addition the effectiveness in using nuclear weapons effects codes to quantify the propagation is discussed. Uncertainties in the models are described.

The purpose of this study has been two-fold: (1) to review and assess the current understanding and modeling of nuclear disturbed environments and their impact on UHF radio propagation, (2) to determine the significance of various nuclear propagation effects to the AFWL alternate concepts, and recommend designs or operational employment practices to mitigate them. In the following sections a succinct summary of the important points and conclusions of this work is given along with future study recommendations, key issues and uncertainties in propagation predictions. Attempts to use high altitude nuclear effects computer codes as communications system design tools are fairly new. In the past such codes have been used in studying the possible effects of nuclear weapons on specific fixed communications systems and have also been a valuable tool for analyzing waveforms and transmission techniques for ABM radar systems. The radar diagnostic use was preceded by sizable R&D programs which provided some theoretical consistency in the understanding of nuclear effects. Of importance to those systems are short time scales (less than 5 minutes). Unfortunately an extension of this work to longer times of interest to communications is not straightforward and is hampered by the paucity of relevant test data. There have been very few high altitude tests and there has never been a multi burst test. Predicting many aspects of a high altitude nuclear environment beyond about five minutes is an area of ongoing future research and preliminary products of this research effort should be used with great caution in system design studies. Effects which scale as the integrated electron density along a propagation path such as dispersion, Faraday rotation, signal delays and their time variation can be currently predictable in magnitude and spatial extent with reasonable confidence. Absorptive effects and refractive effects including signal scintillation require more detailed

assessment of system capability, including propagation and associated link connectivity, is required in order for the MEECN System Engineer to develop a viable MEECN.

The purpose of the Tri-Service Propagation Program, as established by the Defense Communications Agency (DCA), is to develop a reliable and accurate propagation prediction capability that will allow the system engineer to plan for the deployment and operation of the above joint assets and to reliably assess communication performance through an increased understanding of the propagation environment. The accuracy of VLF/LF propagation prediction computer codes is sensitive to the ionospheric parameters used in the analytic process. These parameters: electron density, ionospheric height, and electron-neutral particle collision frequency cannot be specified by single valued functions, rather they are found to vary greatly with respect to time, season of year and geographic location. This phenomenon, while not surprising to the ionospheric physicist, has often been misleading to system planners when analyzing propagation predictions.

This report shows the development of a capability to make predictions of TM-mode signal levels during normal propagation conditions at midlatitudes and for frequencies below 60 kHz. The need exists to extend this capability to higher latitudes and to include the TE-mode of propagation. With these additional abilities for making accurate predictions, realistic operational conditions, under which existing and future improved VLF/LF MEECN links are to operate, can be assured. A task of the Tri-Service Propagation Program is to identify and mathematically describe the ionospheric electron density profiles and other geophysical parameters which, when used with the propagation prediction computer codes, will insure that reliable evaluation of system performance can be achieved.

Comment: This technical report describes part of the current Tri-Service efforts in the acquisition of VLF/LF propagation data over several propagation paths. The midlatitude geographic area is examined in detail in this report. Analysis of data recorded over other paths will be reported separately.

Evaluation: Useful.

critical ports from a worst case EMP, (2) equipment failure models were developed to provide circuit-level EMP susceptibility analyses of selected repeater station subsystems (3) a system assessment model was developed to analytically predict system burnout probability as a function of EMP magnitude and to provide a desired confidence level based on the data generated by the other two models. The data derived from the facility study are summarized as quantitative predictions of repeater burnout probability. Three system assessments were performed based on the energy coupling and equipment failure models. One used the unmodified outputs of these models to predict survival for the system under analysis. The other two analyses assumed that some or all of the system had backup battery power for the power supplies. Results indicate that the unmodified system will almost certainly fail at 50 Kvolts/meter threat but that only a 50 percent chance of failure exists when partial power backup is used. If all power supplies have backup, the system will almost certainly survive. This methodology is therefore suitable for survivability assessment and as a useful tool in any system hardening program.

Evaluation: Useful.

110. D. D. Babb, et al., "Analysis of Communications Systems; Vol. 2, Appendices A, B, and C." AFWL-TR-74-149, Vol. 2. The Dikewood Corporation, Albuquerque, N.M., March 1976. (U) AD-B010598L.

Scope/Abstract: Appendices supporting Vol. I of this report; see Vol. 1 for abstract.

Evaluation: Useful.

111. "MEECN Technical Report. Determination of Effective Ionospheric Electron Density Profiles for VLF/LF Propagation". Tech. Pub. C650-TP-76-4. Defense Communications Agency, Washington, D.C. 1 January 1976 (U).

Scope/Abstract: TACAMO aircraft (Navy), airborne command posts (Air Force) and certain fixed site transmitting facilities provide strategic communications capability in the very low frequency (VLF, 15 to 30 kHz) and the low frequency (LF, 30 to 60 kHz) ranges. These communication systems are considered to be the most survivable in a nuclear war environment.

The Minimum Essential Emergency Communications Network (MEECN) requires a high probability of correctly receiving a message during disturbed conditions. Therefore, an accurate knowledge and/or

107. Loren L. Dickerson, "The Nuclear Hardness Assessment of the Safeguard System", Ballistic Missile Defense Systems Command, Huntsville, Ala. May 1976 (SRD). AD-C010420

Scope/Abstract: This document describes the assessment of the nuclear hardness of the Safeguard system. Consideration of approach taken to implement the system hardening is briefly described. The major subsystems i.e., Sprint, Spartan, Missile Site Radar, Perimeter Acquisition Radar, etc. and the means of obtaining the overall hardness assessment are described. In addition, methods and approaches used by Safeguard and the lessons learned in conducting this effort are also given.

Comment: This report contains an extensive reference list of reports which describe the hardening studies for the Safeguard System.

Evaluation: Useful.

108. D. Taska, S. Stokes III, and J. Quine, "EMP Surge Suppression Devices Utilizing Metal Oxide Varistors for High Frequency Applications", HDL-CR-76-008-1, Harry Diamond Laboratories, Adelphi, Md.; Performing Agency: General Electric Co., Space Division, Philadelphia, PA., March 1976 (U).

Scope/Abstract: This report summarizes the analytical and experimental work performed in developing a surge suppression assembly for high frequency applications utilizing metal oxide varistor materials. The goal of this effort was the development of a terminal protection device for EMP protection whose insertion losses for normal signal conditions do not exceed 1 dB for signal frequencies up to 100 MHz.

Evaluation: Useful in limited areas.

109. D. D. Babb, et al., "Analysis of Communications Systems, Volume I, Assessment Methodology". AFWL-TR-74-149, Vol. I. The Dikewood Corporation, Albuquerque, New Mexico. March 1976 (U). AD-B010596L.

Scope/Abstract: An engineering methodology is presented for analytically predicting the probability of burnout in a microwave repeater station subject to an incident electromagnetic pulse. The project was divided into three related but separate tasks: (1) energy coupling models were developed to estimate coupling to

than that of the TM-mode signal by at least 45 dB under the disturbed condition assumed in the present calculation. In additional, the horizontally polarized TE mode waves are more attenuated than the TM-mode wave under the normal condition.

Evaluation: Useful in limited areas.

105. T.S. Lin, et al., "Vulnerability Assessment for Airborne Launch Control Center." AFWL-TR-75-10-VOL-1. TRW Systems Group, Redondo Beach, Calif. June 1976 (S). AD-C006589L.

Scope/Abstract: This report presents the analysis, data, and results for a nuclear vulnerability assessment of the Airborne Launch Control Center System (AN/ASW-28). The system was evaluated for EMP and nuclear radiation response.

Comment: This report describes a specific hardware test and analysis program.

Evaluation: Useful.

106. W. Chestnut, A Burns, J. Depp, G. Johnson, R. Basku, V. Gonzalez, W. Jaye, and R. Leadabrand, "Analysis and Interpretation of Microwave Measurements of Low-Altitude Nuclear Fireballs", SRI.

also

R. C. Anderson, H. G. Horak, E. M. Jones, J. W. Kodin, M. T. Sanfrod, C. D. Sutherland, and J. Zinn, "Near Surface Phenomenology" Los Alamos. Two papers in "Third Joint Strategic Sciences Meeting Vol 1," AIAA Meeting, June 1976. (S/RD)

Scope/Abstract: These papers discuss low altitude effects on Fireballs. The SRI paper is concerned with radar effects and the LASL paper with hydrodynamics.

Evaluation: Useful in limited areas.

103. H.A. Blank and Staff, "Investigations of the Vulnerability/ Survivability of Systems Supporting the NCA Decision Process." DNA 4295F; CSC/TR-76/3016. Computer Sciences Corporation, Falls Church, Virginia. August 1976 (S/FRD). AD-C016313

Scope/Abstract: This report analyzes several key communications elements and components of the Worldwide Military Command and Control System (WWMCCS) in support of the National Command Authority (NCA). The report places emphasis on existing and programmed Satellite systems, Airborne Command Posts (ABNCP) and terrestrial communications consisting mainly of the Defense Communications System (DCS) and Technical Control Facilities. This initial effort concentrates on NCA-to-European Theater of operations to scope the NCA decision process in that area of interest. The technical topics embodied in this report develop an assessment methodology for future automation of communications and critical message performance capabilities for various crises, details survivability/vulnerability features of certain WWMCCS support systems/subsystems in a stressed environment, and results in some specific conclusions and recommendations for improved capabilities, or additional study and analysis. Furthermore, a preliminary architecture for a computer based assessment tool is discussed and postulated for future consideration and implementation.

Comment: This subject has received a great deal of attention in the last several years, and this report is probably out of date in most areas.

Evaluation: Useful in limited areas.

104. Francis J. Kelly, Franklyn J. Rhoads, Iris P. O'Neal and Monroe Y. McGown, "Very Low Frequency (VLF) Propagation Predictions for Disturbed Conditions." NRL Report 8017. Naval Research Laboratory, Washington, D.C. 27 July 1976 (U). AD-B013284L

Scope/Abstract: A comparison of theoretical VLF attenuation rate predictions for a nuclear disturbed ionosphere shows that the Naval Electronics Laboratory Center (NELC) waveguide program and the GE TEMPO WEDCOM Program agree very well in the calculation of the first order transverse magnetic (TM) mode attenuation rates. The agreement for the second order TM-mode attenuation rates is not as close, but the differences are not very significant for practical predictions.

Between 10 and 25 kHz, for a 4-Mm path length, the cumulative attenuation of the transverse electric (TE) mode signal is greater

studied with relative ease as a function of source parameters (e.g., polarization, azimuth, elevation, planarity, and uniformity) and system configuration.

This report contains the results of a scale-model study of the SAFEGUARD PAR site in North Dakota. The model used to obtain data for this report was built to 1:100 scale of the PAR site. A reasonable effort was made to scale the conduit runs and yard piping entering the PAR Power Plant.

Comment: The use of scale modeling may have application to the SENTRY Program.

Evaluation: Useful.

101. "Nuclear Hardness Assurance Guidelines for Systems with Moderate Requirements", AWFL-TR-76-147, Air Force Weapons Laboratory, Kirtland AFB, NM, September 1976, (U), AD A030609.

Scope/Abstract: Life cycle survivability includes both hardness assurance (HA), applicable during the production phase, and hardness maintenance (HM), applicable during the operational phase. This report presents an approach to an HA program applicable to production of aeronautical systems and other systems with comparable nuclear S/V requirements. The HA program is considered compatible with the general approach taken to develop and verify a hardened design during the RDT&E phase to support the formulation and implementation of a cost effective, but adequate HA program.

Evaluation: Useful.

102. P.E. Silverstein, "Vulnerability Assessment for VHF-FM Radio-Telephone System." AFWL-TR-75-11-Vol-1. TRW Systems Groups, Redondo Beach, Calif. August 1976. (S). AD-C007543L.

Scope/Abstract: This report presents the analysis, data and results from a nuclear vulnerability assessment of the VHF-FM Radio-Telephone System. EMP and ionizing radiation environments were particularly considered.

Comment: A hardware-oriented test and analysis study.

Evaluation: Useful.

"Design of Structures to Resist Nuclear Weapons Effects." ASCE Manual of Engineering Practice 42.

Evaluation: Useful in limited areas.

98. "Hardened Dome Antenna Study". SG 4253-0949. Sperry Gyroscope Co., Great Neck, New York. December 1976 (S) AD-C009359.

Scope/Abstract: This report describes a hardened radar antenna designed to withstand environments (blast, nuclear and thermal radiation) substantially higher than ordinary BMD radars. The radome baseline design is described, then analyses of its response to structural and thermal environments are presented. An electrical properties investigation was also reported. The design appeared to be adequate to withstand the nuclear environments postulated for this system.

Evaluation: Useful in limited areas.

99. Richard C. Scott and Gary D. McCartor, "SCATTR, A Computer Code for Predicting the Effects of Low-Altitude Nuclear Explosions on the Performance of Tropospheric Scatter Links." DNA 4302F; MRC-R-309. Mission Research Corp., Santa Barbara, California. December 1976 (C). AD-C014744

Scope/Abstract: Models are developed for rain, lofted dust and entrained moisture due to low altitude nuclear explosions. VORTEX code phenomenology is used to calculate fireball parameters. Effects of multipath and co-channel interference on tropospheric scatter system performance due to scatter from the stem are calculated. It is shown that these effects persist for much longer periods than effects previously considered. A computer code, SCATTR, for calculating these effects is presented.

Evaluation: Useful.

100. A. Cuneo, Jr. and J. Loftus, "Scale Modeling for the Perimeter Acquisition Radar (PAR) EMP Test", HDL-TR-1761, Harry Diamond Laboratories, Adelphi, MD., September 1976 (Unclassified).

Scope/Abstract: Electromagnetic scale modeling to complement full-scale (EMP) testing of large systems has been used successfully. The coupling of electro-magnetic fields into external system receptors, as well as the effects of complex scattering, can be

96. Gary H. Price and V. Elaine Hatfield, "VLF/LF Propagation Beneath Irregularly Perturbed Ionospheres." DNA 4250F; SRI Project 5056. Stanford Research Institute, Menlo Park, California. January 1977 (U). AD-A043501

Scope/Abstract: The disturbance to very-low-frequency and low-frequency propagation produced by numbers of large-yield, low-altitude nuclear detonations is considered. The consequent lower-ionospheric irregularity both reduces the coherent reflection and produces an incoherently scattered component of the signal. These effects are found to be appreciable at detonation densities in the range of those considered in conjunction with large-scale attack scenarios.

Evaluation: Useful.

97. Curtis Lang, "Vulnerability Characteristics of Emergency Operating Centers (EOCs) in Blast-Risk Areas". Agbabian Associates, El Segundo, California. January 1977. (U) AD-A035868.

Scope/Abstract: Estimates were obtained of the total cost and average unit cost, dollars per square foot, for reducing the vulnerability of all emergency operating centers (EOCs) to nuclear weapons effects except for fallout and EMP. Reduction of vulnerability was interpreted as an upgrading of all EOCs located in high risk areas, i.e., areas where expected air blast overpressures equal to or exceed 2 psi. The upgrade would provde a capability to functionally resist the nuclear weapon effects corresponding to a 10 psi air blast overpressure caused by a 1 megaton surface burst.

Two sets of total cost and average unit cost data were generated. The first set provides cost for upgrading below ground and partially exposed EOCs and for relocating totally above ground EOCs to underground or below ground spaces, i.e., basements of other existing buildings or below ground future conventionally constructed buildings. The second set of costs reflects upgrading of below ground and partial exposed EOCs and new construction of below ground hardened EOCs to replace existing totally above ground EOCs.

Comment: This report contains an analysis of the costs associated with increasing the capability of EOCs (Emergency Operating Centers) to withstand 10 psi overpressures. A statistical sampling of EOC's across the country was made to determine the probable cost estimates. Other references of interest are: 1) C. Lang, "Blast-Resistant Characteristics of State & Local Emergency Center (EOC's)". Agbabian Associates, El Segundo, California. October 1975. AD A016663 (U). 3) American Society Civil Engineering,

to about 5 megatons before about 10 seconds. After that time the effects can be substantial for a wide range of detonation altitudes. However, uncertainties in the model description of the heated air outside the fireball at late times prevent accurate quantitative characterization of blackout behavior at these times.

Evaluation: Useful in limited areas.

94. "Safeguard Operational Experience Program. Part 1." Ballistic Missile Defense System Command, Huntsville, Ala. February 1977. (U) AD-B019912.

Scope/Abstract: The objective of the Safeguard Operational Experience Program was to identify and document unique BMD experience gained during the short operational life of the tactically deployed Safeguard System. As a result the SOEP report is a frank, hopefully objective document that does not hide the growing pains of a system as large and complex as Safeguard. Much of the experience is objective and represents individual opinion, thus it should not be interpreted as official statements of the BMD program manager. Other reports include "Nuclear Hardness Assessment of the Safeguard System" to be published in 1976; and "Safeguard Operational Experience Design and Support Maintenance," published in September 1976, and "Safeguard EMP RFI Lessons, Vol. I and II," dated 31 December 1975.

Comment: This document provides a good summary of problem associated with Safeguard deployment. It also references several other reports.

Evaluation: Useful.

95. D. H. Divis, and B. S. Coffey, "Microwave Blackout Regions from Nuclear Bursts", SAI-77-243-HU, Science Applications, Huntsville, Ala. January 1977, (C) AD-C009654.

Scope/Abstract: This report provides a comparison of the spatial extent and the duration of plasma absorption caused by nuclear bursts for selected frequencies from S Band to millimeter wavelengths. In addition, it begins to access the perferred frequencies, and the preferred burst altitudes to alleviate the nuclear effects on signal propagation. Discussion of the importance of the absorption of millimeter waves from heated undisturbed air modules is provided.

Comment: Frequencies of 3, 10, 35, and 94 GHz were considered. The WEPH code was used to predict ionization and resulting effect on propagation.

Evaluation: Useful.

The effect of numerous parameters affecting the predicted HF outages were discussed. These factors are classified into three groups - Granger Sounder operating characteristics, debris region phenomenology, and D-region absorption characteristics. Several technical areas are identified in which further studies are recommended.

Evaluation: Useful.

92. A.H. Michelet, "A Methodology for Evaluating Adaptive HF/VHF Communication Systems in a Nuclear Environment." DNA 4367T-1; MRC-R-298. Mission Research Corporation, Santa Barbara, California. February 1977 (S). AD-C014746

Scope/Abstract: A general system evaluation methodology for adaptive and quasi-adaptive communication system concepts is described in terms of a set of specific analyses designed to aid in assessing the performance of such systems operating in a nuclear environment. The structure of the suggested approach is designed to permit the progressive isolation of the more important signal space parameter ranges and ionospheric space parameter ranges of the system concept being evaluated. In addition to reducing overall analytical and computational requirements, this approach provides some insight as to the relative importance of the different natural and nuclear burst produced phenomena which can disturb the propagation environment, thus helping to establish priorities for extending or developing techniques to eliminate key phenomenology deficiencies. The evaluation methodology is discussed in the context of two specific proposed HF communication system concepts.

Evaluation: Useful.

93. M. S. Miller, "The Effects of Shock-Induced Atmospheric Reionization on Radar Blackout." BRL Report 1961. USA Ballistic Research Lab, Aberdeen Proving Ground, Maryland. February 1977 (S/FRD). AD-010262L.

Scope/Abstract: An assessment is made of the extent to which radar blackout caused by a nuclear air burst is perturbed by interactions between the atmospheric deionization chemistry and the hydrodynamic shock wave. Chemistry is described by the WEPH-D code with the addition of a collisional detachment to the reaction set. The shock is described by the AFWL 1 Kiloton Standard code scaled to various detonation altitudes and weapon yields. Sensitivity analysis is extensively employed to assess the reliability of the several assumptions required in using a 1-D shock model. It is concluded that the blackout modification is generally slight for all yields up

90. G. J. Burke and A. J. Poggio, "Numerical Electromagnetic Code (NEC) Method of Moments", NOSC TD-116, AFWL-TR-76-320. Naval Ocean Systems Center, San Diego, California 18 July 1977, (U) AD-A075289.

Scope/Abstract: The Numerical Electromagnetics Code (NEC-1) is a computer code for analyzing the electromagnetic response of an arbitrary structure consisting of wires and surfaces and free space over a ground plane. The analysis is accomplished by the numerical solution of integral equations for induced currents. The excitation may be an incident plane wave or a voltage source on a wave, while the output may include current charge density and electric and magnetic fields in the vicinity of the structure. Hence, the code may be used for antenna analysis, EMP or scattering studies. Part 1 of the document includes the equations on which the code is based and a discussion of the approximation method used in the numerical solution. Some comparisons to demonstrate the range of accuracy of the approximations are also included. Details of the coding and the User's Guide are to be provided as parts 2 and 3.

Evaluation: Useful.

91. Warren A. Schlueter, "HF Communications Effects Following Kingfish and Checkmate." DNA 4333T; MRC-R-316. Mission Research Corporation, Santa Barbara, California. May 1977 (S/FRD). AD-C013880

Scope/Abstract: This report describes predictions of HF sky-wave link performance following nuclear bursts using the HFNET computer code. This code was designed to study the performance of large numbers of links after large numbers of nuclear bursts using improved phenomenological models of late time fission debris regions. The utility of the code is shown by comparison between predicted values and test data for two nuclear test events.

Specifically the report compares predicted and measured lowest observed frequency (LOF) data from Kingfish and Checkmate for several HF links which were part of the Granger Sounder communication experiment of Operation Fishbowl. Information on several important operational characteristics, especially transmitter power and receiver sensitivity, were not available, so that predictions of LOF were limited to include those physical parameters relating to D-region absorption.

88. S.L. Gutsche, W.A. Schlueter and R.H. Christian, "Integrated Nuclear Communications Assessment (INCA): HF Attenuation Caused by an Air Defense Nuclear Detonation." DNA 4353T-1A; MRC-R-335. Mission Research Corporation, Santa Barbara, California. 15 August 1977 (S/FRD). AD-C015216

Scope/Abstract: This report describes one phase of the current MRC effort in support of the Integrated Nuclear Communications Assessment (INCA) Program. Presented here is information relevant to the computation of HF absorption following an air defense nuclear detonation. Detailed phenomenology calculations providing information relative to nuclear debris cloud size, rise, and location are presented, along with brief descriptions of the codes used to generate them. Comparisons of code results with test data relevant to the air defense burst are made. Calculations of D-layer attenuation for an interesting array of problem parameters (times, frequencies, ranges) are presented. General conclusions are provided, insofar as they can be derived from examining phenomenology and attenuation calculations. The appendix provides a detailed discussion of direct fireball attenuation at HF frequencies. A second report was written to address the impact of the calculations presented here on the performance of a specific communications system.

Evaluation: Useful.

89. R. A. Perala, "Performance Predictability of the USAF Survivable Low-Frequency Communication System (SLFCS) in a Nuclear Environment", (U), AFWL-T-76-173, MRC-II/1-M-012. Mission Research Corporation, Albuquerque, New Mexico. August 1977 (S).

Scope/Abstract: The results of a brief study of the Survivable Low-Frequency Communications System (SLFCS) performance in a nuclear environment are presented. The study was limited to the effects on the propagation path. The results show that system performance is predictable in a benign environment with a worst case error bound of 50 to 55 dB. Predictions for a nuclear environment have a greater error bound. While significant effort can improve the benign environment predictions, it does not appear possible to determine the nuclear environment error bounds at this time.

Evaluation: Useful.

115. "Project APACHE Program Plan". DNA 3735D. Defense Nuclear Agency, Washington, D.C. and CINCPAC, Honolulu, Hawaii. 1 October 1975. (U). AD-C006517L.

Scope/Abstract: This plan defines the objectives, scope, methodology, schedules and documentation of Analysis of Pacific Communications for Hardening to EMP (APACHE). This analytical and testing effort led to an extensive series of tests and hardening recommendations. Participants in the tests were: CINCPAC; DNA (APACHE Project Manager); Boeing Aerospace Co., BDM; CSC; GTE-Sylvania; ESL; AT&T; IRT; IITRI; MITRE; and SRI. Appendices describe HEMP, list site data requirements, and provide a classification guide.

Evaluation: Ueful in limited areas.

116. S.L. Gutsche and D.H. Sowle, "HF Blackout in a Highly Disturbed Environment." DNA 3802F; MRC-R-187. Mission Research Corporation, Santa Barbara, California. 11 September 1975 (SRD). AD-C005992.

Scope/Abstract: A study is made of the absorption of HF communications signals in the nuclear environment caused by a mass attack on the United States. The effects of meteorological conditions, particularly wind profiles, on the outage times are observed. Average communications link reconstitution times, sensitivity of the result to time of day of the attack, effects of debris stabilization altitudes, and seasonal dependencies are examined for 12 specific links of interest.

Comment: Among the scenarios considered in this report is an attack on Minuteman. The cloud expansion and subsequent motion after that attack are estimated and the resulting HF outage times computed.

Evaluation: Especially valuable.

117. Taylor W. Washburn and Georgellen H. Smith, "Adaptable HF Communication Systems for Use in a Nuclear Environment." DNA 3796T; SRI Project 2511. Stanford Research Institute, Menlo Park, California. September 1975 (S). AD-C006002

Scope/Abstract: A number of techniques are outlined for improving the performance of HF communication systems in a nuclear environment. Emphasis is placed on flexibility rather than increased system margin. The prime requisite for a new-generation HF system

is a technique for diagnosing ionospheric conditions in real time. Also, the communication system must have sufficient frequency agility and versatility to exploit the diagnostic information. Modulation schemes can also be designed to minimize degradation of channel quality. HF line-of-sight and/or groundwave relay links are suggested as supplements to skywave systems in conditions of severe absorption.

Evaluation: Useful.

118. E.F. Vance, "Design Guidelines for Treatment of Penetrations Entering Communication Facilities", Defense Communications Agency, Washington, D.C.; Preparing Agency, Stanford Research Institute, Menlo Park, CA, August 1975 (U).

Scope/Abstract: The EMP-induced transients on conductors such as power lines, communication cables, and waveguides are described. The theory and practice of treating these conductors that penetrate communication facilities are developed to guide the communication-system designer in providing EMP-resistant facilities. The use of current-diversion and voltage-limiting techniques and the role of building shields and facility ground systems in EMP-resistant design are described.

Evaluation: Useful in limited areas.

119. C.M. Crain, "An Overview Discussion of Propagation Effects of Nuclear Environments on VLF-LF Communication Systems." DNA 3778T. The Rand Corporation, Santa Monica, California. 31 August 1975 (U).

Scope/Abstract: It is the purpose of this brief overview to bring out the general features of long-wavelength propagation at VLF and LF frequencies, how nuclear environments can degrade the normal communications capability which these systems provide, and the consequences of remaining uncertainties in predicting the degree of degradation expected under worst-case conditions.

Evaluation: Useful in limited areas.

120. J.D. Illgen, "Analysis of Typical Theater Army Communication Links in a Nuclear Environment," HDL CR-75-016; GE75TMP-17. General Electric - TEMPO, Santa Barbara, California. July 1975, (SRD). AD-C002803.

Scope/Abstract: The effects of rudimentary nuclear scenarios on representative Theater Army Communication Links are determined. Link parameters are defined using various communication concepts defined by INTACS. Nuclear burst parameters are chosen to provide illustrative time duration and magnitude of effects. Only propagation effects due to atmospheric and ionospheric disturbances are considered. The data are intended to identify potential problem areas and provide guidance for performing more detailed analyses. Recommendations for future analysis are provided.

Evaluation: Useful.

121. The Boeing Company PREMPT Group, "Communication Facility EMP Response". DNA 3759F; D180-18163-7. The Boeing Company, Seattle, Washington. DNA 3759F. 30 April 1975 (U). AD-C005325

Scope/Abstract: This document describes a prediction methodology which can be used to determine the electromagnetic and functional response of communication facilities to high altitude EMP. It contains an evaluation of the present response prediction capability based on the results of TEMPS testing of two AUTOVON facilities (Polk City, Florida, and Delta, Utah) and one Tropospheric Scatter Radio Terminal Set. A summary of PRESTO, a computer code used to perform the prediction calculations on a CDC 6600 digital computer, is included.

Comment: This report is part of the PREMPT program. It contains a useful section on the interpretation of EMP test data.

Evaluation: Useful.

122. Warren S. Knapp and Kenneth Schwartz, "Aids for the Study of Electromagnetic Blackout", DNA 3499H, GE74TMP-33, General Electric Company-TEMPO, Santa Barbara, California. 25 February 1975 (U). AD-A010228.

Scope/Abstract: This report is a revision of DASA 2499 (same title) and replaces that document. The report is a compendium of selected graphs, charts, equations, and relations useful in the analysis of electromagnetic blackout caused by nuclear explosions. Information

is provided on weapon outputs, ionization source functions, deionization, absorption, phase effects, and noise. The report also contains sections listing atmospheric properties, physical constants, definition of symbols, and a glossary of frequently used terms.

Evaluation: Especially valuable.

123. E.F. Vance, "Electromagnetic-Pulse Handbook for Electric Power Systems", DNA 3466F, Stanford Research Institute, Menlo Park, CA, February 1975 (U), AD-A009228.

Scope/Abstract: This handbook provides formulas and data for evaluating coupling of the high-altitude EMP to electric power systems and to facilities served with commercial electric power. The subjects covered include coupling to power transmission and distribution lines, transient coupling through transformers, lightning-arrestor firing characteistics, and coupling through the service entrance. Grounding, EMP protective measures, and testing are also discussed.

Evaluation: Useful.

124. T.J. Barret, R.J. Hare, C. Hebner, and J. Thompson, "Bremsstrahlung Radiation in a Nuclear Environment", GE74TMP-34; General Electric-TEMPO, Santa Barbara, Cal. (C), December 1974. AD-C000483L.

Scope/Abstract: This report investigates the importance of bremmstrahlung from nuclear weapon detonations in the atmospheres as an RF noise source. Analysis indicates that bremmstrahlung can be a significant noise source for low altitude, less than 5 to 10 km bursts. Bremmstrahlung is more important for the lower radar frequencies. Comparison is made with available experimental test data base.

Evaluation: Useful.

125. "Component Damage/Malfunction Levels." Technical Memorandum TM-75. Boeing Aerospace Company, Seattle Washington. December 1974 (U). AD-005617

Scope/Abstract: Damage/malfunction thresholds for mission-critical EMP-sensitive equipment of the SAFEGUARD Tactical Support Equipment have been determined by analysis and by laboratory tests. For inductive components and equipment, insulation breakdown is the damage mechanism. For equipment contaning solid-state semiconductors, burnout of the sensitive piecepart governs. For low-voltage capacitors, overvoltage at the capacitor is the damage mechanism. Methods used to calculate the damage/malfunction thresholds are given along with a summary of the laboratory test results.

Evaluation: Useful.

126. Warren S. Knapp, Kenneth Schwartz, James H. Thompson, and William McNamara, "Electromagnetic Blackout Handbook", (U) Third Edition, Volume I - Introduction to Nuclear Weapon Effects, Weapon Outputs, and Phenomenology of Heated Regions." DNA 3380H-1, GE74TMP-3, General Electric Company-TEMPO, Santa Barbara, California. 1 September 1974 (SRD). Also Volume II, DNA 3380H-2, and Volume III, DNA 3380H-3.

Scope/Abstract: This DNA-sponsored handbook provides source material on nuclear weapon phenomenology, atmospheric processes, and effects of disturbed atmospheric environments on electromagnetic propagation for use in analysis of radar and communication systems. This edition of the handbook is a revision of DASA 1580 and DASA 1580-1 (same title) and replaces those documents. The handbook is divided into seven chapters plus appendices published in three volumes. Chapter 1 provides an introduction to nuclear weapon effects on electromagnetic propagation and a summary of communication and radar system performance in nuclear environments. Chapters 2, 3, and 4 present detailed descriptions of weapon radiations and energy deposition in the atmosphere, the phenomenology of heated regions, and atmospheric processes affecting weapon-produced, atmospheric ionization. Chapters 5, 6, and 7 describe electromagnetic propagation effects and weapon-produced noise sources affecting radar and communication systems. The several appendixes include material on the properties of the atmosphere and earth's magnetic fields, reference material on electromagnetic propagation and thermal radiation, and parametric scaling for weapon-produced regions and effects.

Comment: The three volumes of this set have the following AD numbers:
Vol. I: AD-532188 (SRD/CNWDI).
Vol. II: "Atmospheric Ionization and Electromagnetic Propagation Effects." AD-C000208 (SRD/CNWDI)
Vol. III: "Appendices." AD-C000218 (CFRD)

Evaluation: Especially valuable.

127. "Safeguard Communications Agency EMP Effects Analysis and Test Program, Final Report. Volume 1, Summary." M 74-220 Vol. 1. Mitre Corp., Bedford, Mass. 15 August 1974 (SRD). AD-C000137.

Scope/Abstract: The Safeguard Communications Agency has conducted an EMP test analysis program over the past four years. This program is directed towards assuring EMP hardness of the critical communication facilities utilized in support of the Safeguard system implementation. An extensive EMP test program consisting of both laboratory and field evaluation of communication facilities was conducted. It involved the combined efforts of SAFCA and various contractor personnel.

This report is prepared as the final documentation of the SAFCA EMP test analysis program, and summarizes significant findings from all sources within the SAFCA program and from appropriate similar programs.

The activities summarized cover a broad spectrum and have necessitated producing a multi-volume report. The volumes are not designed to provide the details of each activity or finding but rather to summarize and interrelate program efforts into final recommendations. In general, the details provided in the report volumes are in inverse proportion to the volume of information previously published on a specific subject. Throughout the report source references are indicated and use of these references is urged as significant detail is desired on a particular subject.

Comment: Volume 1 summarizes the overall SAFCA EMP program, findings and recommendations.

Evaluation: Useful.

128. "Safeguard Communications Agency EMP Effects Analysis and Test Program, Final Report. Volume 2, Transient Predictions and Coupling Program Analyses." M74-220 Vol. 2 Mitre Corp., Bedford, Mass, 15 August 1974. (SRD). AD-C000138.

Scope/Abstract: The Safeguard Communications Agency has conducted an EMP test analysis program over the past four years. This program is directed towards assuring EMP hardness of the critical communication facilities utilized in support of the Safeguard system implementation. An extensive EMP test program consisting of both laboratory and field evaluation of communication facilities was conducted. It involved the combined efforts of SAFCA and various contractor personnel.

Comment: Volume 2 summarizes program activities in regard to simulation of the specified EMP threat, the development and application of EMP transient estimating models for predicting EMP induced transients internal to the Safeguard communication support stations, and presents station by station transient predictions.

Evaluation: Useful.

129. "Safeguard Communications Agency EMP Effects Analysis and Test Program, Final Report. Volume 3, SAFTCS Equipment/Subsystem EMP Susceptibility." M74-220 Vol. 3 Mitre Corp., Bedford, Mass, 15 August 1974. (SRD). AD-C000139.

Scope/Abstract: The Safeguard Communications Agency has conducted an EMP test analysis program over the past four years. This program is directed towards assuring EMP hardness of the critical communication facilities utilized in support of the Safeguard system implementation. An extensive EMP test program consisting of both laboratory and field evaluation of communication facilities was conducted. It involved the combined efforts of SAFCA and various contractor personnel.

Comment: Volume 3 summarizes the findings from program activities related to identifying equipment responses. The modeling activities were applied to predict the responses of the integrated communications support system and to provide an assessment of the equipment responses envisioned as a result of individual station transients developed in Volume 2. A brief description of the facilities used to derive the critical Safeguard communications circuits is also presented.

Evaluation: Useful.

130. "Safeguard Communications Agency EMP Effects Analysis and Test Program, Final Report. Volume 4, SAFTCS Equipment/Subsystem EMP Susceptibility (Appendices)." M74-220 Vol. 4 Mitre Corp., Bedford, Mass, 15 August 1974. (SRD). AD-C000140.

Scope/Abstract: The Safeguard Communications Agency has conducted an EMP test analysis program over the past four years. This program is directed towards assuring EMP hardness of the critical communication facilities utilized in support of the Safeguard system implementation. An extensive EMP test program consisting of both laboratory and field evaluation of communication facilities was conducted. It involved the combined efforts of SAFCA and various contractor personnel.

Comment: Volume 4 presents detailed information supporting Volume 3 data needed to clarify or amplify specific points of Volume 3. The results of testing conducted on equipment not ultimately utilizing support of the SAFTCS is also presented.

Evaluation: Useful.

131. "Safeguard Communications Agency EMP Effects Analysis and Test Program, Final Report. Volume 5, Transient predictions and Coupling Program Analysis (Appendices)." M74-220 Vol. 5 Mitre Corp., Bedford, Mass, 15 August 1974. (SRD). AD-C000141.

Scope/Abstract: The Safeguard Communications Agency has conducted an EMP test analysis program over the past four years. This program is directed towards assuring EMP hardness of the critical communication facilities utilized in support of the Safeguard system implementation. An extensive EMP test program consisting of both laboratory and field evaluation of communication facilities was conducted. It involved the combined efforts of SAFCA and various contractor personnel.

Comment: Volume 5 presents detailed information supporting the analysis and results presented in Volume 2.

Evaluation: Useful.

132. "EMP Preferred Test Procedures", DNA 3286H, Defense Nuclear Agency, Washington, D.C. 20305. Preparing agency: IIT Research Institute, Chicago, Illinois. August 1974 (U).

Scope/Abstract: Recommended EMP Test Procedures are provided to evaluate or characterize the performance of filters or surge arrestors. Areas covered in detail are experiment design, documentation, representative EMP induced transients, and test procedures to evaluate the EMP behavior of surge arrestors and filters.

Evaluation: Useful.

133. D. Hampel and R. Stewart, "EMP Hardened CMOS Circuits", Harry Diamond Laboratories, Washington, D.C.; Preparing agency: RCA, Advanced Communications Laboratory, Sommerville, NJ, July 1974 (U).

Scope/Abstract: This report presents the results of a study concerning vulnerability of CMOS integrated circuits to transient pulses to determine an optimum method for protecting these devices against EMP-induced effects. The protection network normally used to protect the inputs of MOS integrated circuits against static discharge pulses was then re-designed to provide protection against the more severe EMP environment.

Evaluation: Useful in limited areas.

134. C. E. Brewington, M. E. Brown, H. A. Lasilter, D. R. Martin, H. F. Slater, and L. Vaughn, "U.S. Army Communications Command Electromagnetic Pulse Program Requirements (U) - Executive Summary", Combat Developments Division ACSFOR, Ft. Huachaca, Arizona. June 1974. (S) AD 532191.

Scope/Abstract: This executive summary, U.S. Army Communications Command, Electromagnetic Pulse Program Requirements, consists of a brief description of the final program and listing of the significant findings, conclusions and recommendations regarding the various derivative studies performed as a basis for developing the proposed USACC EMP program. The proposed program is influenced by DOD guidance, DNA, the DCA preempt program, AFCA EMP program results, and the mission and future functions of USACC. The overall study consists of derivative studies addressing the following areas: the DOD EMP program, EMP threat to ACC communications, USACC communications system description, communications system performance criteria, USACC EMP program, USACC EMP program five year cost, USACC

EMP organizational structure of missions and functions, and the EMP simulation facilities and services available in the DOD.

Summary: This report describes briefly the rationale for an Army program to study EMP. The relationship to other programs as well as the rationale behind the proposed program are described. (Very little useful information for the current project.)

Evaluation: Of little value to Sentry.

135. Captain William P. Dotson, Jr., "Network Analysis and the Reliability Assessment of Systems," AFWL-TR-74-138. Air Force Weapons Lab, Kirtland AFB, New Mexico. June 1974 (U).

Scope/Abstract: A self-contained treatment for the reliability assessment of systems is presented. Testing and/or analysis is used to derive estimates of subsystem reliability. Network analysis is used to determine the system reliability from the subsystem reliability. Examples of a number of applications are presented for the ARPA computer network. The problem of optimum allocation of a fixed budget in system assessment/hardening/design problems is addressed, and approaches are proposed. These methods can be used to reduce the high cost associated with system level testing. Some problems that could lead to theoretical extensions are presented, and approaches are proposed.

While the technology discussed herein is slanted toward communications systems in application, it should be noted that it is in no way restricted to systems of that type. It may be applied equally well to the reliability assessment of any system which can be divided into statistically independent subsystems and described in terms which relate the system function(s) to the ability of the subsystems to perform their respective functions.

Comment: A methodology for solving network analysis problems is presented and discussed. This technique was apparently computerized but no reference to the code is given. The mathematical technique is flow diagrammed.

Evaluation: Useful in limited areas.

136. Howard Frank, "Survivability Analysis of Command and Control Communications Network - Part 1" AFOSR-TR-74-1774; IEEE Transactions on Communications, COM-22, No. 5, May 1974. Network Analysis Corp., Glen Cove, N.Y. May, 1974. AD-A001888 (U).

Scope/Abstract: This extract from an IEEE journal describes the network analysis problem in general terms with simple examples showing the importance of correctly modeling the network (e.g., using correlated links when nuclear effects are widespread), and demonstrating the large number of permutations to analyze even a modest network. Part 2 of this report should contain network analysis model details.

Evaluation: Useful.

137. J. Ross Heverly, W. M. Mazer, William Nesbitt, and H. Schroeder, "Communications and Target Acquisition Concepts in Tactical Nuclear Warfare" GRC-OAO-CR-34, General Research Corporation, McLean, Virginia. April 1974 (S) AD 530153L.

Scope/Abstract: This report on communications and target acquisitions concepts in tactical warfare presents a discussion of shortcomings affecting the tactical nuclear option. Significant information is presented concerning the European Theater concepts for automation of communications and display systems and on the vulnerability of the communications net to nuclear bursts. The design of a unified display system facility is described. Its elements include a communications interface data bank, briefing display, and a limited capability for data processing. The system would be almost entirely composed of off-the-shelf hardware.

Comment: Contains a general description of the hardening problem, but no technical information.

Evaluation: Of little value to Sentry.

138. E.J. Baumann, D.L. Nielsen, G.H. Smith and W.E. Jaye, " An Overview of HF Communications in a Nuclear Environment." DNA 3301T. Stanford Research Institute, Menlo Park, California. March 1974 (U). AD-529694

Scope/Abstract: An assessment is made of the ability of HF communication systems to perform in a nuclear environment. Instead of estimating a general percentage reliability, a number of specific situations are listed in which HF will or will not work in various time frames. The impact of ambient ionospheric conditions is stressed. Major areas of uncertainty are isolated and their probable effects on performance estimated. Finally, the scenario-dependence of reliability estimates for all types of communication systems is place in perspective.

Evaluation: Especially valuable.

139. John M. Kamm and Michael W. Sharp, "High-Frequency Propagation in a Disturbed Environment." AFWL TR-73-249. Air Force Weapons Lab, Albuquerque, N.M. February 1974, (C) AD-529354.

Scope/Abstract: The high-frequency radio spectrum has long been considered unreliable for transmission of information through a nuclear disturbed environment. Recently, these frequencies have come under examination for use in future systems and for equipment upgrading. The Air Force Weapons Laboratory (AFWL) has performed many computational studies to answer specific questions about high-frequency performance. This report is an attempt to present unclassified information relating to that problem. It is intended to present general results from specific solutions at specific frequencies.

Summary: This report contains a series of calculations of propagation of HF at frequencies from 2 MHz to 32 MHz as a function of time after a nuclear weapon detonation. The results show that portions of the HF spectrum can be useful in a nuclear environment. The useful frequencies change with time after the event. The results indicate that a specific analysis should be undertaken for each frequency under consideration.

Evaluation: Useful.

140. R. L. Bogusch, D. M. Cottel, R. W. Hendrick, A. H. Michelet, T. E. Old, R. C. Scott, and W. R. Winton, "Nuclear Effects on Safeguard Radar Performance Final Summary Report" MRC-R-120, Mission Research Corp., Santa Barbara, California. February 1974. (S) AD 529303L.

Scope/Abstract: The primary emphasis of this support effort has been to provide improved predictions or nuclear effects on Safeguard radar performance to develop advanced techniques to analyze these effects. Areas of accomplishment include models of radar refraction, clutter and striation effects, quantitative estimates of uncertainty, nuclear effects prediction and development of an advanced method of evaluating radar hardware and software performance. Much of the work accomplished under this contract is documented elsewhere, in nine special technical reports. These reports are briefly summarized in the first section of the final report. Contains an extensive set of references.

Evaluation: Useful.

141. "EMP Hardening of GFE", AFWL-TR-74-61, Air Force Weapons Laboratory, Kirtland AFB, NM; Preparing agency: Boeing/Braddock, Dunn and McDonald, Inc., Albuquerque, NM, July 1973 (U), AD-918276L.

Scope/Abstract: This report presents a preliminary methodology for the analysis and EMP hardening of Government Furnished Equipment (GFE). The proposed methodology considers design factors related to the unique problems associated with modifying existing equipment (e.g., cost and logistics). An example is presented, including vulnerability threshold analysis, hardening technique selection, and hardening verification.

Evaluation: Useful.

142. "EMP Electronic Design Handbook", AFWL-TR-74-58, Air Force Weapons Laboratory, Kirtland AFB, NM; Preparing agency: Boeing/Braddock, Dunn and McDonald, Albuquerque, NM, April 1973 (U), AD-918277.

Scope/Abstract: This handbook provides a compilation of EMP hardening design information in a format of immediate use to electronic designers. Candidate hardening techniques are identified and their

implementation discussed. A supporting test program is outlined but not emphasized.

Evaluation: Useful.

143. "Systems Applications of Nuclear Technology; Radar and Communication Blackout Effects on Air Force Systems," AFSCM 500-9. Air Force Systems Command, Andrews AFB, Washington, D.C. 15 June 1972 (SRD).

Scope/Abstract: The purpose of this manual is to present a general discussion of the electromagnetic blackout phenomena resulting from a nuclear explosion and their effects on Air Force radar and communications systems. Where available, scaling formulas and useful approximations are presented to provide the reader with a qualitative description of the expected environment. In some cases, outputs from computer codes based on test data and theoretical calculations are presented to show definite trends.

Comment: This report gives a good overall description of the blackout problem. A good historical review of data sources is provided. The report provides tables, graphs, and example problems that would allow approximate calculations to be made to compare with more sophisticated results. The Report contains 13 pages of references which have been used to compile the report. Chapter 6 also provides a rationale for doing more detailed calculations.

Evaluation: Especially valuable.

144. S. Dairiki and E. F. Vance, "Cable System Analysis - Volume 1, Network Analysis." AFWL-TR-71-100, Vol. I. Stanford Research Institute, Menlo Park, Calif. August 1971. AD 887452L (U).

Scope/Abstract: An analysis has been made of the propagation of transient electromagnetic pulses in a large network of doubly shielded cables. The cable network is analyzed as a series of coupled transmission line segments connected together. Voltage waveforms were computed at cable junctions and at the ends of branches for several current waveforms injected at one point in the network. The injected pulse shapes included a slow rising exponential pulse and a zero-rise exponential pulse obtained when the cable is driven by a short dipole immersed in a fast-rising exponential-pulse field.

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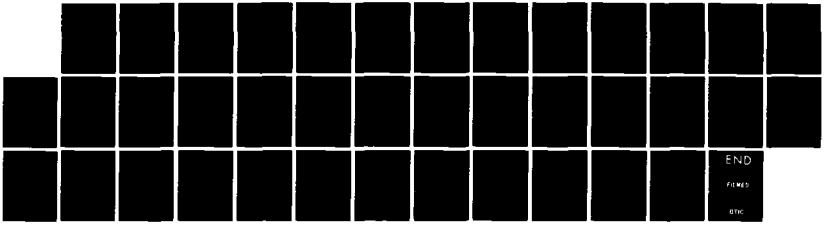

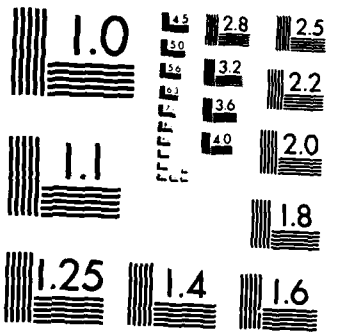

Comment: This report contains an analytical methodology for calculating transient behavior in a network. The sample calculations indicate that slowly varying pulses transmit with little attenuation where as fast transients are usually damped significantly.

Evaluation: Useful.

145. E. Vance, S. Dairiki, and G. Baumgartner, "Cable Systems Analysis, Volume II, Applications to WS-133." AFWL-TR-71-100, Vol. II. Stanford Research Institute, Menlo Park, California. September 1971 (SRD).

Scope/Abstract: Coupling of the EMP to the Hardened Intersite Cable (HIC) core has been reviewed to examine the effects of the soil, the cable parameters, and the source characteristics. The implications of the transmission-line-network analysis presented in Volume I have been examined in terms of the EMP-induced pulse on the HIC core and the operational cable system. Components of the cable system, such as the cable, the cable splice cases, and surge arrestors were tested to determine the limits imposed by these components on the operation of the cable system in an environment of large electromagnetic transients. The dielectric strength of the splices and cable insulation was tested, the variation of surge-arrestor activation voltage with voltage rise time was measured, and the shield current required to collapse the shield was computed. The effects of these parameters and the results of the cable network analysis were evaluated in terms of cable-system performance in an operational system exposed to a transient electromagnetic-pulse environment.

Evaluation: Useful.

142. D. J. Barnes, E. F. Vance and J. A. Martin, "Analysis of Candidate Safeguard Cable Communication Systems," SRI 1-5542. Stanford Research Institute, Menlo Park, California. August 1971 (SRD) AD 527953L.

Scope/Abstract: An analysis of the effects of the nuclear EMP on candidate cable systems for the Safeguard Communication System has been made. Two candidate shielded cables and two commercial repeater systems were examined. The current voltage induced on the coaxial tubes in the interstitial pairs were calculated for ten mile long segments of the cable for high altitude nuclear bursts and for a range of distances from a surface burst. The effect of the induced voltage and current on components of the repeater system was examined and the potential failure modes were predicted. In order

to evaluate the repeater systems and each system was studied in considerable detail. Thus, much detail on system design and operation is included in this report.

Evaluation: Useful.

147. Raymond Kub and Jim Anderson, "Estimate of Currents on Safeguard Site Communication Cables Due to EMP." Analysis Report #SSA/AN-21. 16 June 1971 (U). AD-C009359.

Scope/Abstract: A typewritten memo of less than 10 pages with an analysis specific to the Safeguard configuration.

Evaluation: Of little value to Sentry.

148. "Communications System Survivability Study." DNA 2800F; CSC 4088-18. Computer Sciences Corp., Falls Church, Virginia. February 1971 (S). AD 519715

Scope/Abstract: Prior studies evaluating high altitude EMP (HEMP) on communications land lines indicated it is necessary to include the system nodes in the analysis. The term "transmission facility marshalling point" (TMP) was adopted to define these nodes. A TMP is a point where communications channels are multiplexed or demultiplexed for distribution or extended transmission. This study defines the characteristics of these TMP's and evaluates their vulnerability to HEMP. It then identifies possible traffic chokepoints which could occur within the AUTOVON system in the Washington, D.C. area.

Comment: This report deals with the Autovon network and is not directly relevant to hardened Sentry C^3.

Evaluation: Of little value to Sentry.

149. "Laboratory Electromagnetic Pulse Test Plan", U.S. Army Safeguard communications Agency (SAFCA), Fort Huachuca, Arizona, August 1970. (U)

Abstract: This report describes an EMP Simulator Located at Ft. Huachuca. The general plan for testing Safeguard equipment is described.

Evaluation: Useful in limited areas.

150. Roy A. Smith, "Estimation of Radio Communication Facility Vulnerability to EMP." 70TMP-31. GE/TEMPO, Santa Barbara, California. May 1970 (S). AD-509142.

Scope/Abstract: EMP Analysis of a Defense Communications System (DCS) facility. This is an unhardened microwave system with a 200' tower and a soft equipment building.

Evaluation: Useful in limited areas.

151. E.T. Pierce, "The Thunderstorm as a Source of Atmospheric Noise at Frequencies Between 1 and 100 kHz." DASA 2299; SRI Project 7045. Stanford Research Institute, Menlo Park, California. June 1969 (U). AD-854636

Scope/Abstract: This report surveys the characteristics of the radio noise due to lightning. Many sources of information are used, and several of the problems involved in intercomparison of these data are discussed.

It is shown that the noise pulses emitted by an intracloud flash are predominantly of the "K" type. Experimental information on the durations of intracloud discharges, and on the time separations of the K pulses within a discharge, is summarized. Theoretical results for the amplitude spectrum of an individual K pulse are given; these are compared with experimental data. The amplitude variability of K pulses is estimated.

A consideration of the various types of pulses generated by a flash to earth indicates that the disturbance associated with the leader stage is of little significance; K pulses are of more importance, but the strongest signals are radiated by return strokes. The temporal, spectral, and amplitude characteristics of the return-stroke and K pulses associated with a flash to ground are formulated in an analogous manner to the presentation for the K signals accompanying an intracloud flash.

Knowledge of the electrical behavior for a typical thunderstorm is examined. it is demonstrated that the structure of the noise generated by a storm can be determined from such parameters as flashing rate, proportion of discharges to earth, etc., coupled with information on the pulse emissions due to an individual flash. This procedure can be extended to all global thunderstorms, and estimates are given of the activity associated with each of the major world thunderstorm centers.

Finally, the report indicates how the information it contains could be employed, in conjunction with propagation results, to prepare very sophisticated models of the noise environment, at any frequency between 1 and 100 kHz, for any locality in the world. Such a model would comprise a detailed statistical description in time and magnitude of the incident noise pulses. It would be far more useful for the prediction of possible errors in modern communication systems than the crude--and commonly employed--parameter of mean noise power.

Evaluation: Useful.

152. John C. Ingraham and William S. Kehrer, "EMP Analysis of a Buried Antenna System." Technical Report Number B-4008. EG&G, Bedford, Massachusetts. 28 April 1969 (SRD).

Scope/Abstract: This report presents calculations of the EMP Fields produced by a nearby surface burst at various depths in granite. The interaction of the EMP fields with the radiating elements of buried antennas is estimated. The report also specifies the antenna parameters that affect EMP coupling. The feasibility of protecting the antennas from EMP is discussed. The antennas examined were a small UHF antenna located near the surface and a large MF antenna with elements up to 60 meters long. Interconnecting cables and electronic circuiting were not included in the analysis.

Comment: This study was part of the Hard Rock Silo design effort.

Evaluation: Useful.

153. D. L. Nelson, K. E. Van Landingham, and A. E. Mc Cardell, "Survivability/Vulnerability Study of a Typical Airborne DOD-AIMS Subsystem in a Nuclear Weapon Environment, System 499L". ASD-TR-68-17. Bendix Research Labs, Southfield, Michigan. May 1968 (SRD).

Scope/Abstract: This report describes an analysis of the IFF/SIF, Mark XII equipment on the F111 aircraft and identifies the failure modes, circuit changes, and other hardening techniques to harden the equipment.

Comment: This is a good study to show how a hardening program is implemented.

Evaluation: Of little value to Sentry.

154. C.M. Crain and E.C. Field, "VLF-LF Propagation Degradation in Certain Nuclear Environments." RM-5628-PR. Rand Corp., Santa Monica, California. April 1968 (SRD), AD 389933.

Scope/Abstract: This historical report indicates propagation problems will occur after high altitude nuclear bursts at VLF and LF frequencies. These analyses were done prior to the existence of useful computer programs for this type of calculations.

Evaluation: Useful in limited areas.

155. W. S. Knapp, C. F. Meyer, and P. G. Fisher, "Introduction to the Effects of Nuclear Explosions on Radio and Radar Propagation." DASA-1940. GE/TEMPO, Santa Barbara, California. 15 December, 1967 (U).

Scope/Abstract: This 1967 report provides a tutorial, familiarizing the reader with the nature and order of magnitude of effects rather than providing data for detailed problem solutions. This tutorial is moderately technical and would be very useful if updated. More recent similar information can be found in DNA 3499H, "Aids for the Study of Electromagnetic Blackout," Feb. 1975; and in DNA 3380H; "Electromagnetic Blackout Handbook," three volumes, Sept. 1974. (See previous abstracts.)

Evaluation: Useful in limited areas.

156. "A Study of Structural Vulnerability of Fixed Portions of Hardened Command and Control Systems." BSD-TR-67-208. TRW Systems Group; Space and Missile Systems Organization, Norton AFB, California. September 1967 (SRD).

Scope/Abstract: This study examines the structural vulnerability of fixed, hardened ICBM C^3 elements. Items considered included hardened cables, splices, antennas in several frequency ranges, antenna connections, preamplifiers, and installation techniques.

Comment: This report was part of Hard Rock Silo studies.

Evaluation: Useful.

157. John F. Florey and R. H. Atkinson, "Hardened Communication Cable System Component Test Program". AFWL-TR-66-4. July 1966. AD 377112 (U).

Scope/Abstract: A series of five tests was performed on typical hardened communication capable system components using the High Explosion Simulation Technique (HEST). The components which were tested are typical of those employed in the hardened intersite cable system used in the Minuteman System. The type 6 channel splice case, the AMF splice case, and the ATF splice case were tested on typical cable splices. The facility interface damper and the facility interior clamp were also tested. The test preparation and test results were described in detail. Recommendations are made concerning the design and installation of splice cases and other components.

Comment: This document provides a brief history of exposure of buried cables to blast and shock overpressure. A series of five tests were conducted on typical hardened cable components using a HEST metnodology. The results are tabulated in terms of peak overpressure acceleration and impulse. These results may be indicative of loading on buried cables.

Evaluation: Useful.

158. Richard W. Smith and George W. Lansburg, "Lightning Tests on the Minuteman High Frequency Communications System." AFSWC TR-64-8. Air Force Special Weapons Center, Kirtland AFB, N. M. January 1965 (OUO).

Scope/Abstract: This report describes a series of lightning tests, using a Marx Generator, on a Minuteman HF antenna. The tests were designed to determine induced voltages and currents in certain control cables as a result of lightning strikes on either the transmit or receive antennas. Peak currents were approximately 60 kiloamps; voltages to 244 kvolts. If the lightning arrestors installed on the antennas are functioning correctly, the ratio of induced voltages and currents in the control cables to simulated lightning strikes will remain small through a wide range of strokes (i.e., the antennas survived).

Evaluation: Useful.

APPENDIX B

COMPUTER CODE DOCUMENTATION

FOR SELECTED PROGRAMS

1. Warren S. Knapp and Royden R. Rutherford, "WEDCOM IV: A Fortran Code for the Calculation of ELF, VLF, and LF Propagation in a Nuclear Environment Volume I, User's Manual", DNA 4422T-1, GE77TMP-33-VOL-1. General Electric Company-TEMPO, Santa Barbara, California. October 1977 (C). AD-C014743

Scope/Abstract: This document describes use of WEDCOM IV, a computer code that calculates ELF, VLF, and LF electric and magnetic field strengths in nuclear disturbed environments. The code replaces the previous version of the WEDCOM code (WEDCOM III) documented in DNA 2875F.

2. Warren S. Knapp and Royden R. Rutherford, "WEDCOM IV: A Fortran Code for the Calculation of ELF, VLF and LF Propagation in a Nuclear Environment, Volume II, Computer Routines." DNA 4422T-2; GE77TMP-33-VOL-2, General Electric-Tempo, Santa Barbara, California. 1 November 1978 (U). AD-A066812.

Scope/Abstract: This document describes computer routines used in WEDCOM IV, a computer code that calculates ELF, VLF and LF electric and magnetic field strengths in nuclear disturbed environments. The subroutines in WEDCOM are described and flow diagrams are furnished for most routines.

3. Royden R. Ruthherford, "WEDCOM IV: A Fortran Code for the Calculation of ELF, VLF, and LF Propagation in a Nuclear Environment, Volume 3, Computational Models." DNA 4422T-3; GE77TMP-33-VOL-3. General Electric-Tempo, Santa Barbara, California. 1 November 1978 (U). AD-A066977

Scope/Abstract: The WEDCOM code is a digital computer program that calculates ELF, VLF and LF electric and magnetic field strengths in ambient and nuclear-disturbed environments. The code is intended for use when a relatively detailed analysis of the propagation between two terminals is required in nuclear-disturbed environments. The code can be used alone to study the effects of weapon, atmosphere, and propagation parameters on received signals or can be used in conjunction with receiver antenna and signal processing models to evaluate system performance. This volume of the WEDCOM documentatioon describes the electromagnetic computational models. The ambient and nuclear environment models used in WEDCOM are taken directly from the WEPH VI Code, and are not discussedd in this report.

4. Warren S. Knapp, Royden R. Rutherford, and Kenneth Schwartz, "WESCOM: A Fortran Code for Evaluation of Nuclear Weapon Effects on Satellite Communications. Volume I. User's Manual." DNA 5372T-1. General Electric Company-TEMPO, Santa Barbara, California. January 1981 (S). AD-C027083

Scope/Abstract: The WESCOM (Weapons Effects on Satellite Communications) code is a computer program for use in evaluating electromagnetic propagation effects resulting from the detonation of nuclear weapons on satellite communications systems. The code is intended as a replacement for the SATL code documented in DNA 2796T-1 and DNA 3598T. Volume 1 is the User's Manual for the code.

5. Warren S. Knapp, "WESCOM - A Fortran Code for the Evaluation of Nuclear Weapon Effects on Satellite Communications. Volume 2 - Code Structure." DNA 5372T-2; GE80TMP-30. General Electric Company-Tempo, Santa Barbara, California. 31 January 1981 (U). AD-A102512

Scope/Abstract: The WESCOM code is a computer program for use in evaluating electromagnetic propagation effects resulting from the detonation of nuclear weapons on satellite communications systems. Volume 2 describes the program structure and lists, describes, and flowcharts the program subroutines.

6. D.L. Nielson, J.B. Lomax, and H.A. Turner, "The Prediction of Nuclear Effects on HF Communications." DASA-2035; SRI Project 5481. Stanford Research Institute, Menlo Park, California. November 1967 (U) AD-828676L.

Scope/Abstract: This report describes the theory and implementation of a method for predicting the effects of nuclear weapons on HF communications. Outlined are the development of (1) an ionospheric model that represents both the natural and nuclear-modified electron density profiles along a given path, (2) a propagation model that does not restrict the type or quantity of propagation modes, (3) a method for applying the propagation predictions to a communication system model, and (4) a computer code (NUCOM) for implementing the above.

The ionospheric profiles are represented in terms of several second-order (parabolic and exponential functions. The propagation program traces rays through these profile functions to determine the radio wave characteristics important to a communication system. The calculation of nuclear effets on the ionosphere, of the propagation characteristics, and of the resulting degradation on a generic FSK system are accomplished by using separate computer programs.

Comment: This report is the original work on the NUCOM code. Several models for NUCOM are derived in the appendixes.

7. G. P. Nelson, "NUCOM/BREM: An Improved HF Propagation Code for Ambient and Nuclear Stressed Ionospheric Environments", DNA 4248T, GTE Sylvania, Needham, Massachusetts. 1 October 1976 (U). AD-A058867

Scope/Abstract: The NUCOM/BREM computer code extends the NUCOM II HF propagation code to include direct ray and groundwave propagation modes for airborne and ground-based communications links. Provision is made for user-supplied airborne antenna patterns for both vertical and horizontal polarizations, and for corrected horizontal noise-factors for airborne terminals. A variety of airborne antenna patterns are included and sample links are evaluated. This computer code greatly extends the usefulness of NUCOM II for the analysis of HF links employing airborne terminals and relay aircraft.

8. Jacqueline Owen and Karen K. Bailey, "User's Manual for NUCOM III, An HF Nuclear Effects Code Incorporating WEPH VI - Mod 1", DNA 4824T, SRI Project 5978, SRI International, Menlo Park, California. 30 November 1978 (U). AD-A075321.

Scope/Abstract: This report is a user's manual for NUCOM III, a computer code that predicts the magnitude and duration of nuclear weapon effects on the performance of HF communication systems.

NUCOM III consists of five components: NATPAT, WEPH, ORDER, RAYTRA, and COMEFF. These components operate sequentially to: compute an ionospheric model representative of the natural ionosphere along a path; compute an ionospheric model that accounts for the nuclear effects on the ionosphere along a path; include mechanical wave effects on the ionosphere; compute the characteristics of raypaths using a propagation model that does not restrict the type or number of raypaths that may exist; and combine the raypath characteristics at a frequency and time to obtain an estimate of the communication system performance.

NUCOM III incorporates WEPH VI--Modification 1 as its second component; the previous version of NUCOM (NUCOM II) incorporated WEPH V--Modification 7. This report describes the changes made in the code to incorporate WEPH VI, and other modifications made in NUCOM since NUCOM II.

9. Warren S. Knapp and Kenneth Schwartz, "WEPH VI: A Fortran Code for the Calculation of Ionization and Electromagnetic Propagation Effects Due to Nuclear Detonations. Volume I, User's Manual." DNA 3766T-1; GE75TMP-53. General Electric Company, Santa Barbara, California. September 1975 (U). AD-C005191

Scope/Abstract: This document describes the use of WEPH VI, a digital computer code that calculates atmospheric environment and electromagnetic propagation effects resulting from the detonation of nuclear weapons. The WEPH VI code replaces the previous version of the WEPH code (WEPH V) documented in DNA 2664-1, -2.

10. Warren S. Knapp, "WEPH VI: A Fortran Code for the Calculation of Ionization and Electromagnetic Propagation Effects Due to Nuclear Detonations. Volume 2, Computer Routines." DNA 3766T-2; GE75TMP-53. General Electric Company - TEMPO, Santa Barbara, California. October 1976 (U).

Scope/Abstract: This document describes computer routines used in WEPH VI, a digital computer code that calculates atmospheric environment and electromagnetic propagation effects resulting from the detonation of nuclear weapons. This code replaces the previous version of the WEPH code (WEPH V) documented in DNA 2664-1, -2.

11. Warren S. Knapp, "WEPH VI: A Fortran Code for the Calculation of Ionization and Electromagnetic Propagation Effects Due to Nuclear Detonations. Volume 3, Computational Models." DNA 3766T-3; GE75TMP-53. General Electric Company - TEMPO, Santa Barbara, California. October 1976 (C/FRD).

Scope/Abstract: This document describes computational models used in WEPH VI, a digital computer code that calculates atmospheric environment and electromagnetic propagation effects resulting from the detonation of nuclear weapons. This code replaces the previous version of the WEPH code (WEPH V) documented in DNA 1664-1, -2.

12. Warren Knapp, "Status Report on WEPH Code Modeling - 1978." DNA 4688F. GE-TEMPO, Santa Barbara, California. Nov. 1, 1978. AD A066974 (U).

Scope/Abstract: This report describes changes made to the WEPH code in terms of the atmosphere, atmospheric chemistry and fireball and wake. A description is provided of atmosphere model, ionosphere models, fireball wake and heave models, atmospheric chemistry models, and late time debris models.

13. R.R. Rutherford, "WEPH-SAT System Models." GE78TMP-91. General Electric-TEMPO, Santa Barbara, California. October 1978 (U). AD-B036993L.

Scope/Abstract: This report is one of two reports that document the use of the WEPH VI and WEPH-SAT codes on the DCEC IBM 370 machine. This report describes the new satellite geometry and signal processing models that are appended to WEPH VI to form WEPH-SAT. WEPH-SAT can be used to predict the performance of PSK, DPSK, and FSK digital communication systems in a nuclear environment. Technical and computer program descriptions are provided. (Author)

14. R.R. Rutherford and C.L. Cotner, "WEPH VI/WEPH-SAT User's Guide." GE78TMP-36. General Electric-Tempo, Santa Barbara, California. February 1979 (C). AD-C017614L

Scope/Abstract: This report is one of two that describe the application of WEPH-VI phenomenology to satellite communications analysis problems.

15. Edith J. Feniger and Burt Gambill, "SIMBAL: A Fortran Code for Evaluation of the Effects of Multiple Nuclear Weapons on VLF, LF and HF Communication Links." DNA 5695-1; KT-81-008(R). Kaman Tempo, Colorado Springs, Colorado. 15 May 1982 (C). (Draft)

Scope/Abstract: This report provides instructions and background for users to implement SIMBAL at their facility. An overview of the modeling techniques is provided and user options that will impact running time and accuracy are discussed. Detailed input instructions are provided. Organization of the routines sufficient to allow users to utilize linking or segmentation is provided. A sample problem input is provided, and representative output shows typical format and defines important output quantities.

NOTE: Volume 2, Code Structure, and Volume 3, Computational Models, are still in review.

15. "Project INCA VLF, LF, HF, and VHF/UHF Link Assessment S; Vol. 3, Circuit Mayflower Link Performance Assessment, Atlantic and Mediterranean Areas", DNA 4353F 1G; GTE Sylvania, Inc., Electronic Systems Group, Needham, Massachusetts, January, 1978; (TS).

16. S.L. Gutsche, "Integrated Nuclear Communications Assessment (INCA)--Cemetery Net Performance in an Air Defense Nuclear Environment", DNA 4353T 1B; MRC-R-356; Mission Research Corp., Santa Barbara, California, December, 1977; (SFRD), AD-C015994.

17. P. Fox, R. Aronstein, K. Harper and J. Reese, "Integrated Nuclear Communications Assessment (INCA); The INCA Automated Assessment Tool", DNA 4351T 1B; Computer Sciences Corp., Falls Church, Virginia, November, 1977; (C), AD-C025010.

18. S.L. Gutsche, W.A. Schlueter and R.H. Christian, "Integrated Nuclear Communications Assessment (INCA)--HF Attenuation Caused by an Air Defense Nuclear Detonation", DNA 4353T 1A; MRC-R-335; Mission Research Corp., Santa Barbara, California, August, 1977; (SFRD), AD-C015216.

19. J.W. Dyche, T.H. Neighbors III, R.M. Walker, A.D. Campen, W.E. Sweeney and J.M. Marshall, "Preliminary Theater C3 Nuclear Survivability Assessment", DNA 4354F 3A; BDM-W-77-353-TR; BDM Corp., McLean, Virginia, July, 1977; (SFRD), AD-C014153.

20. J. Marshall, R. Smith and V. Mower, "INCA Propagation Path Effects Assessment for Satellite and Troposcatter Communications in the Tactical Theater", DNA 3825F; ESL TM633; ESL, Inc., Sunnyvale, California, August, 1975; (SFRD), AD-C007979.

21. K.O. Opalka, "Drag Loading on an Antenna Suspended from a Pole", ARBRL MR 03015; Army Ballistic Research Lab., Aberdeen Proving Ground, Maryland, April, 1980; (U), AD-B047955L.

8. "DNA 10th INCA Coordination Meeting Minutes"; The BDM Corporation, Vienna, Virginia; ESL, Inc., Sunnyvale, California; Harry Diamond Laboratories; Computer Sciences Corp., Arlington, Virginia and U.S. Army Signal School, Ft. Gordon, Georgia; June, 1976 (S).

9. J.G. Depp, J. Owen, E.J. Baumann, R.E. Bessey, H.S. Hewitt and C.J. Shoens, "INCA Phase I--Study of the Effect of a Tactical Nuclear Environment on the Performance of EM Systems", DNA 3905F; Stanford Research Institute, Menlo Park, California; December, 1975 (SRD); AD-C009327.

10. J.W. Dyche, J.C. Struthers and W.M. Druen, "Integrated Nuclear Communications Assessment", DNA 3894F and BDM W-6157-75-S; BDM Corp., Vienna, Virginia; July, 1975 (S); AD-C008517.

11. P. Bogue and J. Sanders, "European Theater Command, Control, and Communications (ETC3)", DNA 4351T 2C; BDM Corp., McLean, Virginia; April, 1979 (U); AD-A079947.

12. B.J. Pankowski, G.R. Bailey, G.M. Cravens, J.C. Evans, H.M. Claussen and S.L. Golas, "Communications Degrade Assessment for JCS Exercise Elite Trooper", DNA 4354F 1D; Computer Sciences Corp., Falls Church, Virginia, February, 1979; (S), AD-C019774.

13. M.W. Cross, C.B. Frye and G.P. Nelson, "Project INCA, VLF, LF, HF, and VHF/UHF Link Assessments; Vol. 1, Summary of Results, Threat Definition and Network Characteristics", DNA 4353F 1E; GTE Sylvania, Inc., Needham, Massachusetts, January, 1978; (TS/RD).

14. W.M. Cross, C.B. Frye, G.P. Nelson, D.E. Cook, R.A. Formato, R.V. Nichols, J.B. Murphy and D.E. Marcin, "Project INCA VLF, LF, HF, and VHF/UHF Link Assessment-S; Vol. 2, VLF, LF, HF, and VHF/UHF Link Performance Assessments", DNA 4353F 1F; GTE Sylvania, Inc., Electronic Systems Group, Needham, Massachusetts, January, 1978; (SFRD), AD-C017088.

Part 2. INCA Studies

1. R. M. Walker and G. S. Meader Jr., "Initial Vulnerability Assessment of Existing and NICS Stage I Communications Facilities", DNA 4354T 3B; BDM-W-78-292-TR. June, 1978 (S). AD-C017537.

2. P. Bogue, R. Labash and J. Sanders, "European Theater Command, Control and Communications (ETC3) Model Programmer's Guide", DNA 4351T 2B; BDM/W 78-718-TR. BDM Corp., McLean Virginia. November, 1978 (U). AD-A077617.

3. H. Blank, C. Bohn and G. Kinal, "Integrated Nuclear Communications Assessment (INCA); Transatlantic Trunk Utilization", DNA 4354F 1C; Computer Sciences Corp., Falls Church, Virginia; June, 1978 (U); AD-A067217.

4. H.A. Blank, "Integrated Nuclear Communications Assessment (INCA); Evaluation of Worldwide Airborne Command Post", DNA 4354Z 1B; CSC TR-77-3016; Computer Sciences Corp., Falls Church, Virginia; December, 1977 (S); AD-C017090.

5. "DNA INCA Program Eleventh Coordination Meeting Minutes"; BDM Corp., Vienna, Virginia; ESL Inc., Sunnyvale, California; Harry Diamond Laboratories, Acelphi, Maryland; Computer Sciences Corp., Falls Church, Virginia; GTE Sylvania, Needham, Massachusetts; and Boeing Aerospace Co., Seattle, Washington; November, 1976 (U).

6. "Shape Technical Center Briefing, Integrated Nuclear Communications Assessment Program (INCA)", DNA 76-06673; BDM Corporation, Vienna, Virginia; Stanford Research Institute, Menlo Park, California; ESL, Inc., Sunnyvale, California and Harry Diamond Laboratories, Adelphi, Maryland; September, 1976 (U).

7. H. Blank, "Investigation of the Vulnerability/Survivability of Systems Supporting the NCA Decision Process", DNA 4295F; CSC TR-76-3016; Computer Sciences Corp., Falls Church, Virginia; August, 1976 (SFRD); AD-C016313.

55. "TEMPS/RPG Test Requirements NAVCAMS Eastpac--Buildings 261 and 261A Wahiawa,Oahu, Hawaii", D180 19029 6. November,1977 (U).

56. M. D. Summerlin and R. E. Cronk, "Project APACHE EMP Test Series--No. 1 Test Plan", DNA 4282D. Ken O'Brien and Associates, Albuquerque, New Mexico. September, 1977 (U).

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APPENDIX C

MAJOR NETWORK STUDY REFERENCES

HFNET calculates the deviation of azimuthal arrival angle from the great-circle direction which is caused by ionospheric tilts. Predicted values are substantially smaller than those measured, but this is thought to arise from the use of median ionospheric parameters. That is, small spatial variations in ionospheric parameters are eliminated in the process of reducing large quantities of measured ionospheric data to models of average characteristics.

times or large memory requirements. In most cases the goal of producing a fast running code has resulted in simplified models. For example, the nuclear environment models in HFNET are much less elaborate than those found in detailed, state-of-the-art numerical simulations such as MICE or MELT. The HFNET phenomenology models use orders of magnitude less computer resources while still providing a time-dependent specification of nuclear debris parameters which is adequate for HF propagation effects calculations. On the other hand, the goal of being able to handle large numbers of links and bursts has forced a fairly elaborate simulation structure and sophisticated data management techniques to be incorporated in the code. These features, along with the fast running models, enable HFNET to handle problems much too large for other nuclear environment HF communications codes.

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Scope/Abstract: The ambient sky-wave propagation model in the HFNET computer program is evaluated by comparing predicted results with those from the widely used HFMUFES4 computer program and data from mid-latitude and auroral region propagation paths. The HFNET propagation model consists of two parts--a geometrical model and an ionospheric parameter model.

The HFNET geometrical model uses the virtual height technique with corrections made for ionospheric tilts in and perpendicular to the great circle plane. Good agreement between results from HFNET and HFMUFES4 was obtained when the same ionospheric parameters (for a horizontally uniform ionosphere) were used in both programs. Comparison of program results with data from a 3,260 km mid-latitude propagation path showed good agreement, thereby establishing the validity of the geometrical model.

HFNET predictions were seen to depend upon models of ionospheric parameters. This dependence, of course, applies to all models of sky-wave propagation. HFNET allows the user to select one of two ionospheric models of median characteristics. One model is global in nature while the second model applies only to latitudes greater than about 45°. Comparison of HFNET results using the global model with data from the mid-latitude path shows that the predicted MUF is 5 percent to 20 percent below the average of daily values obtained over a month's time. However, the HFNET values are within the wide range of observed daily variability. For frequencies below the MUF, those generally used so as to avoid the problems associated with operating near the highly variable MUF, predicted and measured characteristics such as elevation angle and mode type are in good agreement. For the case of auroral region propagation, good agreement between predicted and measured values of MUF were obtained.

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Scope/Abstract: This report describes the physical models of the HFNET computer program designed to simulate HF/VHF skywave propagation in a nuclear burst environment. The program has been designed to enable the study of large problems, that is, large numbers of HF/VHF links subjected to effects resulting from large numbers of nuclear bursts. Models of nuclear burst plume characteristics which are important to HF/VHF frequencies have been incorporated to enable the study of radiowave scatter from plume regions. HFNET is the first program enabling the study of potentially increased connectivity resulting from anomalous propagation in the nuclear burst environment. With the orientation towards large problems, we have adopted the philosophy of using analytic approximations to the largest possible extent in all phases of the computer modeling in order to obtain a program which is executable in reasonable times on computers of moderate sizes. HFNET includes a model of the deviation of ambient ionospheric parameters from median values in order to assign a probability of occurrence to predicteed skywave modes and to allow study of modes occurring less than 50 percent of the timee. While such modes may not be of interest to conventional communication systems operating at fixed frequencies between fixed nodes, these lower than average paths may be of high importance to adaptive communications systems.

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Scope/Abstract: This User's Guide describes the HFNET computer program. Separate sections describe program input and output. Sample data and output are provided. HFNET is written in FORTRAN IV and is operational on several types of computers, including the Vax 11/780, DEC 10, CDC 6600 and CDC Cyber/176. Appendices describe the subroutines briefly and discuss the simulation structure.

The HFNET computer code has been developed for the purpose of rapid analysis of nuclear effects on multiple HF to VHF radio links in a multiple nuclear burst environment. The basic philosophy behind HFNET has been to include all effects believed to be important to HF/VHF communications, but to do so in a manner which gives adequate (not necessarily the best) accuracy while avoiding long running

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